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REMEDIAL INVESTIGATION/FEASIBILITY STUDY

Focused Feasibility Study
for Operable Unit Three

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Operable Unit 3 (OU3) at the Woodbridge Research Facility (WRF) has been defined as the Main Ditch (AREE 22) and the area between the northern boundary of the Main Compound and the Main Ditch (portions of AREEs 11 and 17). This report summarizes the site history, current conditions, and environmental data associated with OU3. Human Health and Ecological Risk assessments are presented. General response actions, technology types, and process options appropriate for the remediation of sediment are identified as well as proposed elements for the implementation of institutional controls for the OU. Process options are screened and assembled into six alternatives. Each alternative is evaluated in detail using the nine criteria identified in the NCP (40 CFR 300.430(e)). The report concludes with a comparison of the remedial options under consideration.

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FOCUSED FEASIBILITY STUDY FOR OPERABLE UNIT THREE

FINAL DOCUMENT

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Appendix

A Appendix for Ecological Risk Assessment

B Cost Calculation Worksheets

LIST OF ACRONYMS AND ABBREVIATIONS

ADD ..... Average daily doses

ADI ..... Allowable Daily Intakes

ARAR ..... applicable or relevant and appropriate requirement

AREE ..... Area Requiring Environmental Evaluation

ATSDR ..... Agency for Toxic Substances and Disease Registry

AWQC ..... ambient water quality criteria

BCF ..... bioconcentration factor

BCT ..... BRAC Cleanup Team

bgs ..... below ground surface

BRAC ..... Base Realignment and Closure

BTAG ..... Biological, Technical Assistance Group

CEQ ..... Council on Environmental Quality

CERCLA ..... Comprehensive Environmental Response, Compensation, and Liability Act

CONUS ..... Continental United States

COPC ..... Chemical of Potential Concern

CRAVE ..... Carcinogen Risk Assessment Verification Endeavor

DA ..... dose absorbed

ECAO ..... Environmental Criteria and Assessment Office

EEQ ..... Environmental Effects Quotient

EIS ..... Environmental Impact Statement

EqP ..... equilibrium partitioning

ERA ..... Ecological Risk Assessment

ER-L ..... Effects Range-Low

ER-M ..... Effects Range-Median

FFS ..... Focused Feasibility Study

HDPE ..... High Density Polyethylene

HEAST ..... Health Effects Assessment Summary Tables

HHRA ..... Human Health Risk Assessment

ICF KE ..... ICF Kaiser Engineers

IRIS ..... Integrated Risk Information System

LADD ..... lifetime average daily dose

LDR ..... land disposal restriction

LOAEL ..... lowest-observable-adverse-effect-level

LTEMP ..... Long-Term Environmental Monitoring Program

MAIV ..... mechanically agitated in-vessel
MCL ..... maximum concentration limit
MERDC ..... U.S. Army Mobility Equipment Research and Development Center
msl ..... mean sea level
NCEA ..... National Center for Environmental Assessment
NCBP ..... National Containment Biomonitoring Program
NCP ..... National Oil and Hazardous Substances Pollution Contingency Plan
NEPA ..... National Environmental Policy Act
NOAEL ..... no-observable-adverse-effect-level
NPDES ..... National Pollutant Discharge Elimination System
NPL ..... National Priorities List
O&M ..... Operation and Maintenance
OU ..... Operable Unit
PAH ..... polynuclear aromatic hydrocarbons
PCB ..... polychlorinated biphenyl
PCT ..... polychlorinated terphynles
RA ..... Remedial Action
RAO ..... remedial action objectives
RBC ..... risk based concentration
RCRA ..... Resource Conservation and Recovery Act
RfD ..... reference dose
RI ..... Remedial Investigation
RME ..... reasonable maximum exposure
ROD ..... Record of Decision
SARA ..... Superfund Amendments and Reauthorization Act
SI ..... Site Inspection
SQC ..... sediment quality criteria
SVOC ..... semivolatile organic compound
TAL ..... Target Analyte List
TBC ..... to be considered
TCL ..... Target Compound List
TCLP ..... toxicity characteristic leachate procedure
TPH ..... Total Petroleum Hydrocarbon
TRV ..... toxicity reference value
TSCA ..... Toxic Substance Control Act
UCL ..... Upper Confidence Limit

USAEC..... U.S. Army Environmental Center

USAMC ..... U.S. Army Materiel Command

USEPA..... U.S. Environmental Protection Agency

USFWS..... U.S. Department of Fish and Wildlife Services

UST..... underground storage tank

VADEQ..... Virginia Department of Environmental Quality

VHWMR..... Virginia Hazardous Waste Management Regulation

VOC ..... volatile organic compound

WRF..... Woodbridge Research Facility

EXECUTIVE SUMMARY

ICF Kaiser Engineers (ICF) has been contracted by the U.S. Army Environmental Center (USAEC) to perform a Focused Feasibility Study (FFS) for contaminated media at OU3 within the Woodbridge Research Facility (WRF), Woodbridge, Virginia. This task has been performed under Contract No. DACA-31-94-0064, Delivery Order 001. This Focused FS report presents a summary of the site background, evaluates the risks posed to human health and the environment by conditions within OU3 and identifies and screens remedial measures that are potentially applicable to the site.

In July of 1991, WRF was recommended for closure by the 1991 Defense Base Realignment and Closure Commission under the Base Realignment and Closure Act (BRAC). The property will be transferred to the U.S. Fish and Wildlife Service (USFWS) in the near future. Based on preliminary results of the Remedial Investigation (RI) conducted in 1995/1996, four areas of concern were identified as Operable Units (OUs) by the BRAC Cleanup Team (BCT). Areas Requiring Environmental Evaluation (AREEs) 1 through 7 (Former Dumps, and the former Pistol Range [AREE 7]) were defined as OU1. The Main Compound Area was defined as OU2. The Main Ditch (AREE 22) and the area between the Main Ditch and the northern boundary of the Main Compound (portions of AREEs 11 and 17), were defined as OU3, and all the remaining areas of WRF were defined as OU4.

NATURE AND EXTENT OF CONTAMINATION

The primary topographic feature associated with OU3 is the Main Ditch. The northern portion of this ditch receives surface water runoff from residential and partly industrialized areas to the north and from on-site northern locations. The northwestern branch originates close to the facility entrance and receives runoff predominantly from on-site areas. The two branches converge approximately 1,000 feet from the western facility boundary. Following the convergence of the two branches, the ditch flows predominantly west to east, north of the Main Compound. Approximately 600 feet from the eastern edge of the Main Compound area, the ditch turns abruptly south before ultimately discharging to the Occoquan Bay.

Studies that were conducted in 1993 revealed that sediments in OU3 had been impacted by past discharges of Polychlorinated Biphenyls (PCBs) from the Main Compound. PCB-contaminated sediments were detected in the Main Ditch and also at the outfall area of the former oil/water separator and the former vehicle washrack. These two structures, located in the Main Compound, were considered the likely sources of the PCB discharges and were subsequently removed in a 1995 removal action. During this remedial action, approximately 1100 tons of PCB-contaminated soils were also removed from the drainage swale that extends from Locust Road to the Main Ditch. Pre-removal sampling indicated that the highest concentration of PCBs in the removal area was 16,000 ppm. Post-removal confirmation samples indicated that residual PCBs (i.e., PCB-1260) are present in surface and subsurface soils at concentrations as high as 0.149 and 210 ppm, respectively. These concentrations exceed the residential Risk Based Concentration (RBC) for PCB-1260 which is 0.083 ppm for soils and sediment.

Sediments in the Main Drainage Ditch were further investigated during the 1995/1996 RI. PCB-1260 was detected at concentrations ranging from 0.043 ppm to 6.04 ppm. Additionally, three surface soil samples collected near the PCB excavation confirmed the presence of residual PCBs at concentrations from 0.04 ppm to 0.149 ppm. Two of the three samples collected were above the residential RBC of 0.083 ppm for PCBs in soils. Soil borings and monitoring wells were also installed from which subsurface soil samples and groundwater samples were collected. Six subsurface soil samples had PCB concentrations that exceeded the residential RBC, with the maximum concentration reported as 0.70 ppm. No significant organic compounds were detected in the groundwater samples collected within OU3, with the exception of a sample from monitoring well MW-55 where the pesticide, dieldrin, was detected at a concentration of 0.009 ppb (this exceeds the residential RBC of 0.0042 ppb for dieldrin). Additionally, UST studies at the Main Compound have shown that TPH is present in the groundwater and has the potential to migrate into OU3. TPH-contaminated groundwater could mobilize residual PCB contamination downgradient to the Main Ditch and wetlands areas. Compounds that were detected in groundwater that were identified as COPCs include dieldrin, iron, and manganese.

The 1995/1996 RI also evaluated fish samples collected from areas downstream of where PCBs were detected in the Main Ditch. Pesticides and PCBs were detected in whole body fish samples which

suggests that the fish in the high quality wetlands may be receptors of OU3 contamination. However, the relationship of the fish contaminant concentrations to the OU3 contamination is uncertain due to possible mobility of the fish.

The 1995/1996 RI also detected pesticides in sediments in the northern and northwestern portion of the Main Ditch. Chlordane (total), alpha-chlordane, gamma-chlordane, and DDD were detected and the maximum concentrations of these pesticides were 0.263 ppm, 0.0263 ppm, 0.03 ppm, and 0.024 ppm, respectively. Follow-up sampling was conducted in April and May 1997 to evaluate the extent of pesticide contamination in this area. One sample was collected from a sample location where pesticides were detected during the RI. In addition, one upgradient and two downgradient (from the RI sample location) samples were collected. No pesticides were detected in these samples. Therefore, the pesticides detected during the RI are considered to be very localized and not of concern. The source of the pesticide-contaminated sediments appears to be a result of past routine use of pesticides at the facility, as well as possible migration from up-gradient off-site sources.

SUMMARY OF HUMAN HEALTH RISK ASSESSMENT

A Human Health Risk Assessment (HHRA) was conducted to evaluate potential human health effects associated with exposures to chemicals in sediment, surface water, surface soil, subsurface soil, groundwater, and fish at OU3. Based on the different patterns of contamination in the Main Drainage Ditch of OU3, the sediment and surface water data were separated into two groupings for the human health risk assessment: the PCBs Area (north and downgradient of the Main Compound, where elevated PCB concentrations were detected) and the Pesticides Area (upgradient of the PCB contamination, where pesticide applications and possible on-site migration from off-site sources likely occurred). Surface soil, subsurface soil, and groundwater collected from an area associated with the PCBs Area, located between the northern side of the Main Compound and the Main Drainage Ditch, were also evaluated in the OU3 HHRA. Potential risks associated with exposures to subsurface soil were not quantitatively evaluated since none of the compounds detected in subsurface soil were selected as chemicals of potential concern (COPCs).

Human exposures were evaluated for both current and future land-use conditions. Current land-use conditions reflected the current conditions at the site, while future land-use conditions reflected the most reasonably anticipated future land-uses at OU3. Under current land-use conditions, it was assumed that trespassers/recreational users could be exposed to COPCs in media at OU3. Under the assumption that WRF is to be transferred to the USFWS in the near future, the most likely future land-use conditions (other than those evaluated under current land-use conditions) include exposures to workers and environmental educators. In accordance with regulatory agencies and in order to provide a baseline understanding of worst-case risks at OU3 and to determine the need for institutional controls (especially for groundwater), it was assumed that the site could become residential, and that residents could be exposed to COPCs selected for each of the media.

The upper-bound lifetime excess cancer risks derived in the HHRA can be compared to U.S. Environmental Protection Agency's (USEPA target risk range for health protectiveness at Superfund sites of $1x10^{-6}$ to $1x10^{-4}$. In addition, the noncarcinogenic hazard indices (HIs) can be compared to a value of 1, since HIs greater than 1 indicate a potential for adverse health effects. Based on a directive issued by the USEPA's Office of Solid Waste and Emergency Response, cumulative site risks and hazards to individual receptors were also calculated. The USEPA directive states that, where cumulative carcinogenic site risk to an individual based on reasonable maximum exposure for both current and future land use is less than $1x10^{-4}$, and the noncarcinogenic hazard index is less than 1, action is generally not warranted unless there could be adverse environmental effects.

Under current land-use conditions, potential cumulative risks to trespassers/recreational users exposed to sediment, surface soil, and surface water in the PCBs and Pesticides Areas were at the mid-range of ($3x10^{-5}$ for the PCBs Area) or below (for the Pesticides Area) the target risk range, and the cumulative HIs were below 1.

Potential cumulative risk to future workers exposed to groundwater, surface soil, and sediment in the PCBs Area was at the high end of the target risk range ($1x10^{-4}$) and the cumulative HI was below 1. The potential cumulative risk to future workers exposed to sediment was below the target risk range in

the Pesticides Area. (A cumulative HI was not calculated since none of the COPCS had noncarcenogenic toxicity criteria).

The potential cumulative risk to future environmental educators exposed to sediment, surface water, and surface soil at the PCBs Area was at the high end of the target risk range ($1x10^{-4}$), while potential cumulative risk to environmental educators in the Pesticides Area (evaluated for exposures to sediment only) was at the low end of the target risk range of $1x10^{-6}$. The HIs associated with environmental educator exposures to noncarcinogenic compounds in surface water from both areas were less than 1, indicating that noncarcinogenic adverse effects would most likely not occur. The high risks associated with environmental educators in the PCBs area further supports the need for the establishment of institutional controls in the PCB area.

Although potential risks associated with residential exposures to groundwater, surface soil, sediment, and surface water were evaluated in the HHRA, it should be noted that residential exposures are not likely to occur at WRF because WRF is to be transferred to the USFWS. Potential risks to child and adult residents exposed to groundwater were well below USEPA's target risk range for health protectiveness. The HIs associated residential exposures to groundwater via ingestion exceeded 1 for both the adult (HI=2) and child (HI=5) receptors (both due to iron), indicating that adverse effects could occur if residents were exposed to groundwater under the conditions assumed in the HHRA.

The potential cumulative risk for child residents was above the target risk range for the PCBs Area ($2x10^{-4}$), due to exposure to surface soil and was below the target risk range for the Pesticides Area. The cumulative HI for a child resident was greater than 1 for the PCBs Area (HI= 5), due to ingestion of groundwater and less than 1 for the Pesticides Area.

The potential cumulative risk for adult residents in the PCBs Area was $5x10^{-3}$ (due to fish ingestion and dermal absorption of surface soil), and the cumulative HI was greater than 1 (HI=2, due to groundwater ingestion). It should be noted that the fish ingestion exposure pathway at OU3 is considered highly unlikely for several reasons: 1) residents would not likely reside at WRF; 2) individuals would not likely fish in the OU3 ditch since there are other areas at WRF better for fishing; and 3) the ditch at OU3 is not likely to support large quantities of edible-sized fish.

SUMMARY OF ECOLOGICAL RISK ASSESSMENTS

Risks to ecological resources from the presence of chemicals in the OU3 ditch sediment and surface water were evaluated as part of the OU3 FFS in the Ecological Risk Assessment (ERA). Based on an evaluation of the chemicals detected in the study area and the ecological resources known to occur in the OU3 area, the following ecological receptors/endpoints were selected for evaluation:

- Adverse effects to small mammals (as represented by mink) from the ingestion of chemicals that have accumulated in fish;
- Adverse effects to piscivorous birds (as represented by great blue heron) from the ingestion of chemicals that have accumulated in fish;
- Adverse effects to aquatic life from exposure to chemicals in surface water; and
- Adverse effects to aquatic life from exposure to chemicals in sediment.

The following is a summary of the results of the ERA.

Adverse Effects to Small Mammals and Piscivorous Birds from the Ingestion of Fish

The results of the 1995 RI identified chlordane, heptachlor, PCB-1260, and mercury as the COPCs in fish that could be ingested by mammalian and avian predators at the WRF. The results of the ERA indicated there is a potential for adverse effects to great blue herons from the ingestion of DDT- and mercury-contaminated fish.

Adverse Effects to Aquatic Life from Chemicals in Sediment

PCB-1260 was detected at locations downstream of the discharge ditch from the former oil/water separator and the former vehicle washrack. The results of the ERA indicated there is a potential for adverse effects to benthic organisms from the presence of PCBs in sediment.

Adverse Effects to Aquatic Life from Chemicals in Surface Water

The concentrations of the inorganic compounds detected in the surface waters of OU3 were compared to Federal Ambient Water Quality Criteria (AWQC) (because these criteria are as, or more stringent, than State criteria). The comparison indicated that there is a potential for adverse effects to aquatic life from the presence of barium, copper, iron, lead, vanadium, and aluminum in the surface water of OU3. However, the RI concluded that the chemicals detected in surface water are unlikely to be originating from on-site locations and were most likely attributable to stormwater runoff from upstream/off-site construction. Due to these circumstances, the ERA concluded that risks associated with exposure to this pathway were highly unlikely.

REMEDIAL ALTERNATIVES ANALYSIS

The results of the RI, and previous site investigations show that PCB contamination is present in sediment that could pose risk to human health and the environment. Accordingly, the FFS analyzed several remedial action (RA) alternatives. The first remedial objective is to meet the USEPA, Region III Biological Technical Assistance Group (BTAG) cleanup recommendation for PCB-contaminated sediments of less than or equal to 1.0 ppm for the protection of ecological receptors. An additional remedial objective is the protection of human health from contaminants in groundwater and subsurface soils. This can be accomplished through the implementation of institutional controls restricting groundwater use and soil disturbance.

The following section presents a description of the remedial alternatives that passed initial screening and were considered in detail in this FFS Report. The feasible alternatives are labeled as follows:

Alternative A: No Action

Alternative B: Natural Attenuation/Long-term Monitoring with Institutional Controls

Alternative C: Excavation/Ex-Situ Treatment using Chemical Oxidation/On-Site Placement/ Long-term Monitoring/ Institutional Controls

Alternative D: Excavation/Bioslurry Treatment/On-Site Placement/Long-term Monitoring/ Institutional Controls

Alternative E: Stream Construction and Restoration/Long-term Monitoring/Institutional Controls; and

Alternative F: Excavation with Off-Site Disposal in a Landfill/Institutional Controls/Long-term Monitoring.

Alternative A: No Action

Capital Cost:	$0
Annual O&M:	$7,200
Present Worth (30 years):	$109,795

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) require that the "No Action" alternative be evaluated at every site to establish a baseline for comparison to other alternatives. Under this alternative, no RA of any kind would be performed. Any access controls currently in place would not be maintained. Annual Operation and Maintenance (O&M) costs have been developed to comply with the five year monitoring requirements of CERCLA.

Alternative B: Natural Attenuation/Long-term Monitoring with Institutional Controls

Capital Cost:	$33,861
Annual O&M:	$17,865
Present Worth (30 years):	$308,491

This alternative does not use any technology that reduces toxicity, mobility, or volume of contaminants, but would allow the natural attenuation of PCBs in sediment to continue. Institutional controls would limit future uses at the site.

The purpose of this alternative is to continue limiting access to the site; inform the public of site hazards; provide a database of site conditions; and evaluate changes over time. To assess the effectiveness of the remedy, long-term monitoring would consist of periodic sampling of groundwater, surface water, sediment, and biota. Future long-term monitoring would confirm the impact of surface water runoff with regards to levels of inorganic compounds detected in surface water. The data collected would be reviewed at least every five years, as required by the NCP for all sites where contaminants remain at the site above levels that allow for unlimited use and unrestricted exposure.

Alternative C: Excavation/Ex-Situ Treatment using Chemical Oxidation/On-Site Placement/ Long-term Monitoring/ Institutional Controls

Capital Cost:	$353,000
Annual O&M:	$13,215
Present Worth (30 years):	$556,148

Under this alternative, approximately 550 cubic yards of PCB-contaminated sediments in the Main Ditch would be removed to achieve a clean-up goal of 1.0 ppm. This would be performed during the summer when the water level in the ditch is low. Any water flowing into the ditch would be diverted, thereby allowing easier access for the excavation equipment and minimize the amount of water held in the sediment for dewatering activities. The excavated sediment would be transported to the parking area adjacent to the Main Compound to be used as a dewatering/treatment area. All water that discharges from the dewatering/discharge area will be diverted to a sump and be treated to assure that no contaminated water discharges to the site. The Chemical Oxidation process consists of adding a non-hazardous reagent and water, if required, to the contaminated sediment. The contaminated sediment is mixed in a hopper with the non-hazardous reagent for a minimal amount of time. After treatment, the sediment would be stockpiled near the treatment area and confirmatory samples would be collected for chemical analysis. The clean treated sediment would then be placed back in the excavated ditch.

The technology is an innovative technology and has not been widely used for site remediation. Treatability studies would need to be performed prior to the full-scale remediation of the area in order to determine the effectiveness of this technology for the treatment of sediment contaminated with PCBs. In addition, the treatability study would be used to determine the amount of reagent that would be required to treat the sediment.

The purpose of including long-term monitoring and institutional controls to this alternative is to limit unauthorized groundwater use and soil disturbance; limit site access; inform the public of site hazards; provide a database of site conditions; and evaluate changes over time. To assess the effectiveness of the remedy, long-term monitoring would consist of periodic sampling of groundwater, surface water, sediment, and biota. Future long-term monitoring would confirm the impact of surface water runoff with regards to levels of inorganic compounds detected in surface water. The data collected would be reviewed at least every five years, as required by the NCP.

Alternative D: Excavation/Bioslurry Treatment/Placement of Treated Sediment On-Site/Long-term Monitoring/Institutional Controls

Capital Cost:	$1,693,126
Annual O&M:	$13,215
Present Worth (30 years):	$1,896,274

Under this alternative, approximately 550 cubic yards of PCB-contaminated sediment would be treated using a combination of anaerobic (without oxygen) and aerobic (with oxygen) bioslurry treatment. The sediment would be mixed with microorganisms, nutrients, and other additives in a slurry with the sediments which can range from 20 to 50 percent solids. The differences between the two types of treatment technologies is that aerobic bioslurry is performed in a oxygenated environment while anaerobic bioslurry is performed in an environment devoid of oxygen.

The PCB-contaminated sediment would be treated in a batch treatment process thereby allowing the optimal treatment of the contaminants in sediment. This alternative has been used to effectively degrade PAHs, simple aromatics, petroleum hydrocarbons, and explosives. Research has shown that the most effective process for the treatment of PCBs is to first perform treatment using anaerobic bioslurry to dehalogenate the PCB followed by aerobic bioslurry to breakdown the carbon rings.

This technology is an innovative technology and has not been widely used for the remediation of PCBs . Treatability studies would need to be performed prior to the full scale remediation to determine the effectiveness of this technology for the treatment of sediment at OU3. The treatability studies would also be used to design the final full-scale system.

The purpose of including long-term monitoring and institutional controls to this alternative is to limit unauthorized groundwater use and soil disturbance; limit site access; inform the public of site hazards; provide a database of site conditions; and evaluate changes over time. To assess the effectiveness of the remedy, long-term monitoring would consist of periodic sampling of groundwater, surface water, sediment, and biota. Future long-term monitoring would confirm the impact of surface water runoff with regards to levels of inorganic compounds detected in surface water. The data collected would be reviewed at least every five years, as required by the NCP.

Alternative E: Stream Construction and Restoration/Long-term-Monitoring/Institutional Controls

Capital Cost:	$212,771
Annual O&M:	$16,963
Present Worth (30 years):	$473,535

This alternative would involve relocating the portion of the ditch that is contaminated with PCBs in order to eliminate exposure to this compound by the aquatic communities at WRF, which would then minimize exposure to higher order receptors. The stream would be diverted just upstream from the area where PCBs were detected. A meandering stream would be constructed through the wetlands north of the present ditch and connected to the present ditch, just north of Charlie Road. Aquatic vegetation indigenous to the wetlands at WRF would be planted in the newly constructed stream. It is anticipated that a new benthic community would colonize the new stream within one year. The fill from the newly excavated stream would be placed over the old ditch segment, which would "entomb" the PCB-contaminated sediments. The excavation would be performed during the summer months as described in Alternative C.

An option was considered for this RA alternative which consisted of creating a wetland area that could be constructed in the upper reaches of the Main Ditch. This would be accomplished by widening the drainage ditch and allowing it to "flood". The area of the ditch where the PCBs are present would be covered with the sediment that was excavated in the upper reaches of the ditch. Once this flooded area was created, a wetland habitat would begin to establish itself. It was anticipated that this alternative would be similar in cost as the stream reconstruction alternative.

The purpose of including long-term monitoring and institutional controls to this alternative is to limit unauthorized groundwater use and soil disturbance; limit site access; inform the public of site hazards; provide a database of site conditions; and evaluate changes over time. To assess the effectiveness of the remedy, long-term monitoring would consist of periodic sampling of groundwater, surface water, sediment, and biota. Future Long-term monitoring would confirm the impact of surface water runoff with regards to levels of inorganic compounds detected in surface water. The data collected would be reviewed at least every five years, as required by the NCP.

Alternative F: Excavation with Off-Site Disposal in a Landfill/Long-term Monitoring/ Institutional Controls

Capital Cost:	$204,589
Annual O&M:	$13,215
Present Worth (30 years):	$407,736

Under this alternative, approximately 550 cubic yards of PCB-contaminated sediments in the Main Ditch would be removed as necessary to achieve a clean-up goal of 1.0 ppm. Prior to disposal, Toxicity Characteristic Leaching Procedure (TCLP) and PCB analyses will be performed to assure that the sediment passes criteria for disposal at a local landfill. If these criteria are exceeded, sediments will be disposed of at a Resource Conservation and Recovery Act (RCRA) Subtitle C Facility/Toxic Substances Control Act (TSCA) -permitted disposal facility. However, using the existing knowledge of site conditions, the cost for Alternative F was based on local disposal at a landfill. If the TCLP test results indicate that the sediments fail TCLP, and the facility is required to send the sediments to a RCRA Subtitle C disposal facility, the cost would need to be revised to include the transportation and disposal of hazardous waste at such a facility.

Sediment excavation would be performed during the summer when the water level in the ditch is low. Any water flowing into the ditch would be diverted. The sediment would be staged on the parking lot for dewatering. All water that discharges from the dewatering area will be diverted to a sump where the water will be treated prior to any discharge to the site. Once the sediment has been dewatered to a "bladable" condition, it would be loaded in dump trucks and/or roll-off boxes and transported to a local landfill for disposal.

The purpose of including long-term monitoring and institutional controls to this alternative is to limit unauthorized groundwater use and soil disturbance; limit site access; inform the public of site hazards; provide a database of site conditions; and evaluate changes over time. To assess the effectiveness of the remedy, long-term monitoring would consist of periodic sampling of groundwater, surface water, sediment, and biota. Future long-term monitoring would determine the impact of surface water runoff with regards to levels of inorganic compounds detected in surface water. The data collected would be reviewed at least every five years, as required by the NCP.

COMPARATIVE EVALUATION OF ALTERNATIVES

This section provides a comparative analysis of the RA alternatives. The purpose of this comparative analysis is to identify the advantages and disadvantages of each alternative relative to one another so that the key trade-offs can be identified.

Overall Protection of Human Health and the Environment

All of the alternatives, with the exception of "No Action", would provide adequate protection of human health and the environment by eliminating, reducing, or controlling risk through treatment, engineering controls, or institutional controls. Because the "No Action" alternative is not protective of human health and the environment, it is not considered further in the analysis.

Compliance with Applicable or Relevant and Appropriate Requirements

The primary chemical-specific Applicable or Relevant and Appropriate Requirements (ARARs) (which is technically a "To Be Considered" [TBC] guidance) for OU3 is the cleanup goal of 1.0 ppm PCBs in sediment. This objective has been recommended by BTAG and is based on ecological and toxicological studies. The 1.0 ppm cleanup objective has been used successfully for other sites within Region III. There are also action-specific and location-specific ARARs that are outlined in the FFS for OU3 that will be compiled with as appropriate for the RA. All alternatives would meet their respective ARARs or Federal and State environmental laws, with the exception of the No Action Alternative.

Long-term Effectiveness and Permanence

Although Alternative B may reduce risks by enacting institutional controls and allowing for the natural degradation of chemicals over time, there is little evidence that PCBs would naturally degrade within an acceptable period of time. Alternatives C, D, E, and F would provide permanent solutions using institutional controls and through active treatment technologies (Alternatives C and D) or removal and off-site disposal of the contaminated sediment (Alternative F); or by covering the contaminated area (Alternative E), thereby removing the risk via exposure. Alternatives C and D are innovative technologies and, therefore, the long-term effectiveness cannot be fully assessed until treatability studies are performed. Alternative F provides the best long-term effectiveness and permanence at the site because contaminants will be removed and disposed of off-site.

Reduction of Toxicity, Mobility, or Volume of Contaminants through Treatment

Alternative B, Natural Attenuation/Long-term Monitoring with Institutional Controls, would not reduce the toxicity, mobility, or volume of contaminants through treatment, and may not reduce the toxicity, mobility, or volume of contaminants through natural degradation processes. Alternatives C through D would reduce toxicity, mobility, and volume through active treatment. Alternative E would not reduce volume; however, it would reduce toxicity and mobility by covering the contaminants. Alternative F would reduce toxicity and mobility at WRF, but would not reduce volume because it is being disposed off-site at a landfill. However, Alternative F does remove the contaminated sediments from the site, which will reduce risks to environmental receptors at WRF.

Short-Term Effectiveness

Alternative F would provide best short-term effectiveness because it is easy to implement and will not take a long time to complete. The ecological community will be disturbed in the short-term but is expected to recover such that the short-term effectiveness is still met. Alternative B would not disturb the ecological receptors in the ditch, however, since the contaminants remain at the site, this alternative is not considered as effective in the short-term as Alternative F. Alternatives C and D would provide the least short-term effectiveness due to the treatability studies that will be required prior to implementation. Alternative E would require less time to implement than C and D; however, short-term effectiveness is not completely met, due to the temporary disturbance of the ecological environment in and near the Main Ditch.

Implementability

All alternatives are implementable. Alternative B is the most implementable of all the alternatives because institutional controls would only require a small amount of time to implement. Alternatives E and F would not be difficult to implement. Alternative E would utilize equipment and aquatic vegetation that is readily available. Stream construction design would require professional expertise that is available through services provided by private industry and possibly USFWS. Alternative F would be implemented using technologies that are widely available and there is no special expertise required for the design as in Alternative E. Alternatives C and D would be the most difficult to implement because they are innovative technologies that have not been completely tested for the treatment of PCBs and will require treatability studies prior to the design of the final remedy.

Cost

Cost comparison of the remedial alternatives include the factors of total capital cost, annual O&M costs, and present worth over a 30-year period (discount rate 5%). The cost comparison for the alternatives from least expensive to most expensive are as follows: Alternative B, Alternative F, Alternative E, Alternative C, and Alternative D.

MODIFYING CRITERIA

State Acceptance

State acceptance will be evaluated during the review and public comment period and therefore is not evaluated here.

Community Acceptance

Community acceptance will be evaluated after the public comment period ends and a remedy is accepted.

1.0 INTRODUCTION

ICF KE has been contracted by the USAEC to perform a FFS for contaminated sediment within the WRF, Woodbridge, Virginia. This task has been performed under Contract No. DACA-31-94-0064, Task Order 1. This FFS report presents a summary of the site background, evaluates the risks posed to human health and the environment by conditions within WRF and identifies and screens remedial measures that are potentially applicable to the site.

In July of 1991, WRF was recommended for closure by the 1991 Defense Base Realignment and Closure Commission under the BRAC. Based on preliminary results of the RI conducted in 1995, four areas of concern were identified as OUs by the BCT. AREEs 1 through 6B (Former Dumps) and AREE 7 (Former Pistol Range) were defined as OU1. The Main Compound Area was defined as OU2. The Main Ditch and the area between the northern boundary of the Main Compound Area and the Main Ditch were defined as OU3, and all the remaining areas of WRF were defined as OU4.

The results of previous investigations as well as the RI indicate that sediment in the Main Ditch has been impacted by surface runoff and the primary contaminants of concern are PCBs and pesticides. Therefore, an FFS was performed to identify and evaluate appropriate remedies for the contaminated media at OU3.

This FFS Report addresses OU3. The specific project tasks included in this FFS report are the following:

- Data from sampling performed from previous investigations and RI performed in 1995/1996 are presented;
- An HHRA and an ERA are developed for the specific contaminants present in OU3;
- Remedial action objectives are developed for the specific contaminants, affected media, and exposure pathways;
- Remedial technologies are identified which, alone or in combination, can treat, contain, or dispose of contaminated media;
- The remedial technologies are screened to eliminate those that are not technically implementable, based either on non-attainment of chemical-specific requirements or on the volume of media which must be treated;
- As required under the CERCLA of 1980, as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986, the remedial technologies are assembled into remedial alternatives which, to the maximum extent practicable, utilize permanent solutions and alternative technologies; and
- A detailed analysis of the remedial alternatives is performed using the nine evaluation criteria listed in the NCP.

This FFS has been conducted in accordance with USEPA guidance documents developed for activities performed under CERCLA/SARA; the National Environmental Policy Act (NEPA) of 1969; and the President's Council on Environmental Quality (CEQ) regulations (40 CFR 1500-1508). In addition, the procedures used in the study are consistent with the Department of the Army's policy toward integrating the NEPA and CERCLA/SARA processes.

This study has been performed under the purview of the U.S. Army, USEPA Region III, and the Virginia Department of Environmental Quality (VADEQ).

1.1 REPORT ORGANIZATION

The FFS report consists of the following sections:

Section 1.0 - Introduction

Section 2.0 - Site Background. A summary of the historical data specific to OU3 is presented.

Section 3.0 - Human Health Risk Assessment. The results of the HHRA for the site are summarized. Based on an evaluation of site risks, the rationale for the remedial action and constraints on the remedy are identified.

Section 4.0 - Ecological Risk Assessment. The results of the ERA for the site are summarized. Based on an evaluation of site risks, the rationale for the remedial action and constraints on the remedy are identified.

Section 5.0 – Applicable or Relevant and Appropriate Requirements. The results of the risk assessments are used in developing remedial action objectives. In addition, chemical-, action-, and location-specific ARARs and TBC guidance for potential remedial actions are identified.

Section 6.0 - Identification of General Response Actions. The general response actions potentially applicable to site conditions are identified and discussed. These general response actions are broken down into technology types and process options, which are then screened based on implementability, effectiveness, and order-of-magnitude cost.

Section 7.0 - Detailed Analysis of Alternatives. Each remedial alternative is described in detail. The extent to which each remedial alternative satisfies each of the nine criteria identified in the NCP (40 CFR 300.430) is discussed.

Section 8.0 - Comparison of Remedial Alternatives. The results of the detailed evaluation of remedial alternatives and a comparison of the alternatives are described. The remedial alternatives are ranked in order of their compliance with the nine criteria identified in the NCP so that relative strengths, weaknesses, and trade-offs between the alternatives can be identified.

Section 9.0 - References

2.0 FACILITY BACKGROUND

The following section presents information regarding WRF and, in particular, OU3. This includes information describing the site history; physical setting of the area; the site hydrogeologic setting; a summary of past activities possibly contributing to current environmental problems associated with OU3; a summary of analytical results from previous investigations at OU3; and conclusions derived from those investigations.

2.1 PHYSICAL SETTING

The WRF occupies approximately 579 acres and is situated in the eastern-most portion of Prince William County, Virginia, a short distance from the Washington D.C. metro area, as shown in Figure 2-1. The town of Woodbridge is located just to the west of the WRF. The entrance to the installation is located on Dawson Beach Road, east of U.S. Route 1.

The property immediately to the north of the installation (and to the east of Dawson Beach Road) is presently being developed into a private golf course, residential housing, and a marina. To the north of the WRF (and to the west of Dawson Beach Road), the installation is adjoined by a former military housing area and also by commercial property. The facility is bounded on the west by the Marumsco Creek and the Marumsco National Wildlife Refuge tidal wetlands. West of Marumsco Creek is Veteran's Memorial Park, a recreation area administered by Prince William County. The southern and eastern edges of the property are shoreline, facing the Belmont and Occoquan Bays.

2.1.1 Climatology

The WRF is located in the easternmost area of Prince William County, Virginia near the mouth of the Occoquan River where it empties into Belmont Bay. The climate at the site is variable due to the proximity of both the Chesapeake Bay (and Atlantic Ocean) and the Appalachian Mountains. Average annual rainfall is more than 38 inches and the annual mean daily temperature is 57°F. The coldest month is January and the hottest month is July; the growing season lasts from mid-April to mid-October. Prevailing winds are generally from the south in the summer and from the north/northwest in the winter.

2.2 TOPOGRAPHY AND DRAINAGE

Ground surface elevations at the site range between less than 2 feet to over 30 feet mean sea level (msl). The highest elevations are in the northern and western portions of the site. There are flat-lying areas along the southern and southeastern coastal areas of the site and relatively steep slopes along the southwest coastal area (facing Marumsco Creek) and in the central area of the site (facing the Main Ditch and southeast marshy area). Figure 2-2 is the detailed site topographic map that was constructed with aerial photo data that illustrates the topographic features at WRF.

The WRF site is situated within the Occoquan River basin at its discharge point into Belmont Bay. The Occoquan River and Marumsco Creek are the east and west boundaries of the promontory of land on which WRF is located. The WRF facility is drained by one surface water channel that originates off site and enters the site property near the Dawson Beach Road (Route 687) gate. This primary drainage channel is joined by at least three other tributaries before it reaches Occoquan Bay, just east of Deep Hole Point (see Figure 2-2). Past site activities have included the deepening and straightening of this drainage channel as well as the construction of drainage pathways between existing (natural) drainage features. Because of the known modifications to the natural drainage, this primary discharge channel has been named the "Main Ditch".

2.3 GEOLOGIC/HYDROGEOLOGIC DESCRIPTION

This section presents information on the physical characteristics of the subsurface materials at WRF. General characteristics of soils, geology, and stratigraphy are presented below.

2.3.1 Soils

The soils at WRF have not been mapped specifically. However, the Prince William County soil map indicates that the soils beneath the site include the Dumfries-Lunt-Marr unit and associated soil from

the Neabsco-Quantico-Dumfries unit. The following section is a summary of the information provided in the Soil Survey of Prince William County, Virginia (USDA SCS, 1989).

2.3.1.1 Dumfries-Lunt-Marr

These are very deep, well drained soils that have a loamy or clayey subsoil. This soil unit consists of gently sloping to very steep soils on terraces. The soils are underlain by fluviomarine sediments of sand, silt, clay, and gravel. Minor soil associations in lowland tidal areas include the Featherstone soils.

1. The *Dumfries* soils are on strongly sloping to moderately steep side slopes. They are well drained, very deep, and have a loamy subsoil.

2. The *Lunt* soils are on gently sloping to moderately steep side slopes. They are well drained, very deep, and have a clayey subsoil.

3. The *Marr* soils are strongly sloping to moderately steep. They are very deep, well drained, and have a high content of fine sand and very fine sand.

4. The *Featherstone* soils are present at low elevations. They are very deep, level to nearly level, and very poorly drained.

The Weston (1992) document provided more site-specific information regarding site soils. However, the information reported there has not been corroborated with either the reference provided or follow-up investigation.

2.3.2 General Geology

The WRF site is located within the Coastal Plain Physiographic province which is characterized by a thick wedge of unconsolidated to loosely consolidated sediments ranging in age from Cretaceous to Recent.

Mixon et al. (1989)[1] report that the WRF is underlain by Quatemary-age sediments that were deposited during interglacial high stands of the sea. Two members of the Tabb Formation (Upper Pleistocene) are shown at the site (see Figure 2-3). This formation is comprised of gravel, sand, silt, clay and peat lithostratigraphic units of coast-parallel plains and includes coeval terrace deposits along major rivers. Stratigraphic analysis of this section of the Coastal Plain sequence has been difficult and as a result, the Tabb Formation was defined in order to clarify stratigraphic problems encountered by regional stratigraphers (Johnson and Peebles, 1991). In summary of the work, the distribution of facies within this formation is complex as it reflects both deposition and erosion throughout at least three cycles of transgression/regression within the alluvial depositional setting.

A geologic map has not been developed specifically for the site. However, reconnaissance mapping can be completed based on the Mixon et al. (1989) map and site-specific information such as topography and boring logs. First, the site topography can be divided into two general areas: 1) a low and relatively flay-lying area along the reaches of the Main Ditch and to the south and east of the site which is marshy nearest the shore; and 2) the northern, central, and western areas of the site which are higher in elevation and exhibit an undulating land surface (see Figure 2-2). based on the regional geologic map (Mixon et al. 1989). Information available in Froelich (1985), and existing site information, the higher portions of the site are probably underlain by terrace deposits of the ancestral Potomac River and the lower areas are probably areas where terrace deposits have been eroded away (if ever present) and where more recent steam/river deposits overlie the ancestral Potomac River deposits.

2.3.3 Site Stratigraphy

Cross sections prepared for the WRF site illustrate the complex distribution of subsurface geologic materials. Figure 2-2 depicts cross section location on a site-wide topographic map. Figures

[1] This is a large-scale map of Virginia and, therefore, does not provide geologic detail at the site. A literature search at the U.S. Geological Survey failed to identify any small scale geologic mapping in this area of Prince William County. However, a Fairfax County geologic map (Froelich, 1985) shows similar geology on the land parcel adjacent to the northeast of WRF.

2-4 through 2-13 are the geologic cross sections prepared using boring log data for monitoring wells installed at the site. Boring log data are presented in the RI report prepared for the site (USAEC, 1997). The cross sections depict the variability in site subsurface sediments. For example, the subsurface stratigraphy presented in cross section A-A' (Figure 2-4) includes units composed of either clay, silt, sand, or gravel, and units composed of mixtures of these materials. The correlations shown on A-A' illustrate the laterally and vertically discontinuous nature of the stratigraphic units[2]. Cross section B-B' (Figure 2-5) illustrates what appears to be more continuity in the stratigraphic units. It should be noted that this apparent continuity may be a function of well and/or sample spacing rather than actual conditions. The actual variability in geologic materials may be much greater than that depicted on the cross sections because, in a typical sampling program, wells are not spaced closely enough to allow the delineation of each sand or clay layer/lens in a heterogeneous system. In other words, additional wells installed along any cross section may show that the stratigraphic units are not as extensive as currently shown. Therefore, correlations shown on the cross sections should be considered estimated. The cross sections are useful, however, in illustrating the heterogeneous nature of the subsurface stratigraphy at WRF (vertically and laterally discontinuous units with highly variable grain-size distributions).

Cross section A-A' shows porous, water-bearing units/lenses of silty sand, sand and gravelly sand overlain by a more continuous unit of silty clay that thins to the southwest near Occoquan Bay. The silty sand and sand units depicted on B-B' are also overlain by a silty clay layer that thins near Occoquan Bay. Cross section C-C' (Figure 2-6) depicts permeable units of sand, gravelly sand, and sandy silt that appear to be interbedded or grade into one another so that they may be hydraulically connected. These units are overlain by silty clay that thins on both sides of the section where it nears Occoquan Bay. Cross section D-D' (Figure 2-7) depicts interbedded units of silty sand, sand gravel, and silty clay. Silty clay makes up the surficial deposits except at well MW-76, near Occoquan Bay, where sand outcrops at the surface. Subsurface geologic deposits in the area of the site covered by cross sections A through D appear to have been deposited in an alluvial setting. For example, note the grading of grain sizes A-A' where sand and gravelly sand in well MW-80 appears to grade into sand that grades into silty sand in well MW-60. Similar gradation can be seen in cross section C-C' where sandy silts grade into sand that grades into gravelly sand. The apparently extensive units of near-surface clay and silty clay could have been deposited during interglacial periods. The thinning of surficial clay deposits near the Bay indicates that this layer has apparently been eroded away by surface water bodies.

Cross section E-E' and F-F' (Figures 2-8 and 2-9) depict stratigraphy similar to that discussed above. Porous, water-bearing units of sand, gravelly sand, and silty sand could be hydraulically connected due to gradation between units. Water-bearing units are overlain by a unit of silty clay and clay that appears to be continuous near the surface. This surficial clay unit does not thin or pinch out because these cross sections are not as close to the Bay or Marumsco Creek as cross sections A through D. In fact, the surficial clay unit becomes thicker in upland areas such as beneath the Main Pond near PZ-12 on cross section F-F'.

Cross sections G-G' and H-H' (Figures 2-10 and 2-11), again, are similar to the other cross sections in their depiction of water-bearing units that may be hydraulically connected overlain by a mostly continuous layer of clay/silt. Cross section G-G' depicts a few water-bearing units of sand and gravelly sand that do not appear to be hydraulically connected to other water-bearing units. These units are overlain by a layer of silty clay that likely causes aquifer conditions in these units to be confined. Cross section H-H' depicts more porous units that could be hydraulically connected. Because of the hydraulic connection, these units may act together as one aquifer. This aquifer unit is overlain by a layer of clay and silty clay that could act as a confining unit. However, the clay unit is broken by a silt unit near the surface at MW-66. In the area of this well, the aquifer could be under unconfined conditions or semi-confined conditions if the silt layer is compacted an/or contains clay.

Cross section I-I' (Figure 2-12) was constructed to depict stratigraphic conditions in the area of the Main Ditch. This cross section shows discontinuous, water-bearing units overlain by silty clay or clay that is thicker in upland areas. Based on the presence of clay near the surface in most areas of the site, the Main Ditch is likely underlain by a clay layer that separates it from hydraulic connection to deeper

[2] Stratigraphic units are discontinuous due to depositional (facies changes) and erosional factors.

water-bearing units. However, there are not enough wells installed in the Main Ditch area to confirm this theory. Cross section J-J' (Figure 2-13) depicts similar conditions beneath the Main Compound area. Note that two well clusters were used in cross section J-J' (Figure 2-13) depicts similar conditions beneath the Main Compound area. Note that two well clusters were used in cross section J-J'. In well cluster MW-62/56 (refer to Figure 2-2), only lithologic data from well MW-56 was used in the cross section because MW-62 was drilled using the mud rotary method that does not allow the collection of detailed lithologic data. In well cluster MW-39/84 (refer to Figure 2-2), only lithologic data from well MW-84 was used because well MW-39 is shallow and the boring log does not provide as much lithologic data as the log for MW-84. The boring logs for both wells show similar lithologies, however, MW-39 notes a sand-gravel-silt material of unknown thickness at approximately 6 feet msl that was not noted in MW-84.

In summary, the stratigraphy at WRF is characterized by zones/lenses of porous, water-bearing materials that are hydraulically connected in many areas but are discontinuous in others. These water-bearing materials are hydraulically connected in many areas but are discontinuous in others. These water-bearing units are overlain in most areas of the site by a clay layer that thins near the Bay and thickens in upland areas.

2.4 AQUIFER SYSTEM FRAMEWORK

The shallow groundwater flow system beneath the WRF site is composed of laterally discontinuous clay, silt, sand, and gravel units of varying thickness and sorting that were deposited in an alluvial setting. Hydrostratigraphic units have not been defined at the site because of these lateral and vertical discontinuities, or heterogeneity. Boring logs for on-site monitoring wells suggest that the primary water-bearing units at the site are composed of sand or sand and gravel that is often present below dry clay or silt units (or poorly-sorted mixtures of silt and clay with sand). Because of the high degree of heterogeneity in geologic materials at the site, the extent to which those water-bearing units are hydraulically connected is not known. Therefore, distinct aquifer units have not been identified at the WRF.

Table 2-1 summarizes important hydrogeologic information for most of the monitoring wells at the site. Boring logs were reviewed for each of these wells to estimate the approximate thickness of dry clay or silt above the screened interval, the depth at which water was first encountered during drilling, the number and types of different lithologies screened by each well, and the local aquifer condition at each well. The local aquifer condition (unconfined , confined, or semi-confined) was estimated based on the lithology in each borehole, the elevation of the top of the water-bearing unit screened by the well and the stabilized groundwater elevation (USAEC, 1997).

From the geologic cross sections it is clear that most wells have several feet of low-permeability material (clay or silty clay) at the surface. An examination of geologic information and groundwater elevation at each boring reveals that most wells have a groundwater elevation that rises above the top of the water-bearing unit(s) screened by the well. These observations indicate the presence of confined or semi-confined aquifer conditions within the water-bearing units in the subsurface.

Figure 2-14 is a bar graph of two parameters for each well. The first parameter is the difference in feet between the elevation at which water was first encountered in each of the borings and the elevation at which the water level in the well stabilized (data presented in Table 2-1). This water level variance value is plotted beside the second parameter, the thickness of clay above the well screen. It is clear that there is a positive correlation between these two parameters. Therefore, at well location where thick clay units were observed above the screen, the equilibrated water level measured in the well strongly suggests confined to semi-confined conditions at that depth. However, it should be noted that unconfined conditions appear to exist in several wells (see Table 2-1). These wells are located in both upland and low-lying areas across the site and do not appear to be present in a particular pattern that would indicate unconfined conditions in specific areas. Rather, aquifer conditions are believed to be a function of local lithology at each well.

The complex stratigraphy at the site precludes detailed analysis of any particular hydrostratigraphic unit because the extreme heterogeneity in subsurface geologic materials cannot be fully characterized with standard monitoring well design and placement. The level of detailed attained using existing monitoring well data is insufficient to define hydrostratigraphic units or to map water levels

in each unit beneath the site. For example, monitoring well MW-60 on cross section A-A' is screened across a low-permeability unit of interbedded clay and silt, a water-bearing unit of silty sand, and a unit of silty clay. The resulting groundwater elevation is an average of the hydraulic head in each of these geologic units. Such an average does not allow an accurate evaluation of the hydrogeologic conditions present in the water-bearing unit screened by that well. Therefore, groundwater elevation data used to construct water level maps at this site do not accurately reflect the local-scale groundwater flow conditions in the water-bearing units screened by each well. It should be noted that groundwater elevation data used to construct groundwater contour maps for this site must be clearly identified as to what unit(s) those data represent and what condition is implied with boring data (i.e., confined versus unconfined) such as that provided in Table 2-1.

2.5 GENERALIZED GROUNDWATER FLOW SYSTEM

Two main factors have led to the belief that although complex, the lithologic units in the shallow groundwater system at WRF are probably hydraulically connected throughout the area of the facility. First, the proximity of the regional discharge point (Occoquan Bay) suggests that all groundwater flow in the shallow subsurface will converge on the base level represented by the Bay. For groundwater to reach this regional discharge area, either preferred hydraulic connection pathways exist between water-bearing units or enough leakage occurs through the low-permeability zones separating water-bearing units that water moves from water-bearing unit to water-bearing unit until it reaches the regional discharge area.

Second, when the water level distribution at the site is contoured in the context of both stratigraphy and topography (the main controlling factors), the conditions under which groundwater exists are reflected in the contours. In other words, in areas of low topography (where the thinning or absence of a surficial clay layer allows water-bearing units to be under unconfined condition) the water level contours mimic site topography. At higher elevations, the water level contours (representing water levels within more porous water-bearing units under confined conditions) do not necessarily mimic site topography because groundwater flow in upland areas is controlled by the thickness and distribution of water-bearing units and not on localized surface topography. For example, on cross section H-H' water levels are near the surface in wells installed in areas of low topography (MW-69, MW-65, MW-66, and MW-67) whereas water levels in wells installed in areas of higher elevation (MW-59 and MW-60) are much lower.

The variable topography and complex stratigraphy described in Sections 2.2 and 2.3.3 appear to be the controlling factors on groundwater occurrence in the shallow subsurface at this site. These factors control whether groundwater occurs under unconfined or confined conditions[3] at any given depth and location. The subsurface stratigraphy also controls whether water-bearing units are hydraulically connected to one another. Because of these factors, the resulting water level distribution measured from on-site wells is not what one might expect for typical shallow groundwater (water table) conditions. In other words, because the monitoring wells at the site are not screened in one discreet aquifer[4], the water level distribution measured from on site wells does not represent any particular hydrostratigraphic unit; rather, it represents averaged, or composite, water levels in the shallow subsurface at the site.

Because the water level distribution is complex and aquifer units have not been defined at the site, many interpretations of small-scale groundwater flow patterns can be developed based on the data currently available. In this section, two different interpretations of groundwater flow are presented. The first assumes that water-bearing units are hydraulically connected, leading to an equilibration of water levels regardless of local aquifer conditions (confined or unconfined). The second assumes less hydraulic connections and aquifer conditions that are more dependent on the stratigraphy at each well. The small-scale groundwater flow patterns in either interpretation could prove to be realistic. However, both

[3] This assumption is based on boring log and water level data collected at the site to date.

[4] Monitoring well screens are the standard length of 10 feet and, therefore, are open over two or more different lithologies. The resulting water level represents the (weighted) average water-level condition in each of the screen lithologies. This face even further complicates the understanding of water level distribution at the site. It should be noted that: 1) the monitoring wells were installed to intercept the uppermost water-bearing units; and 2) that prior to installation of the monitoring wells, little was known about the subsurface at WRF. Therefore, the use of 10-foot screens for wells at this site was an appropriate use of standard well installation methods.

interpretations show that the larger-scale groundwater flow pattern at the site is radial with water traveling from recharge areas to the north and northwest of the site toward the regional discharge point of Occoquan Bay.

The first interpretation of groundwater flow is presented in a composite water level map for the site, Figure 2-15. This map combines both water table conditions in low-lying areas of the site (where water levels mimic site topography) and confined or semi-confined conditions in the upland areas of the site (where water levels are independent of site topography) into one map to illustrate the complexity of shallow groundwater flow patterns. It is believed in this interpretation that both confined and unconfined conditions can be represented on a single contour map because water-bearing units are hydraulically connected, resulting in an equilibration of water levels with the regional base level. Therefore, regardless of local aquifer conditions, the nearby regional discharge area is a base level to which water levels equilibrate.

Small-scale groundwater contours are complex, with flow generally moving from topographic highs to lows. The Main Ditch appears to be hydraulically connected to water-bearing units, resulting in unconfined conditions immediately north of the Main Compound area. However, further upstream from that location the lack of wells prevents the characterization of the hydraulic relationship between the surface and groundwater. In the remaining areas of the site, radial groundwater flow dominates.

Second interpretation of groundwater flow is presented in additional groundwater elevation contour maps. Four different contour maps were created based on screen midpoint elevation. Wells whose screen midpoint falls within a 10-foot range in elevation were contoured on one map to illustrate the point that small-scale radial groundwater flow toward regional discharge locations remains evident. These groundwater contour maps, Figures 2-16 through 2-19, depict the behavior of groundwater at four different depths within the shallow aquifer system, 10 to 0 feet msl, 0 to –10 feet msl, –10 to –20 feet msl, and –20 to –30 feet msl. The wells in these maps were assumed to be under a more confined aquifer condition than that depicted in the composite groundwater contour map (Figure 2-15). Therefore, surface water features such as the Main Ditch do not have as much control over groundwater contours on these potentiometric surface maps.

Figure 2-16 presents groundwater contours based on groundwater elevations for wells whose screen midpoint falls between 10 and 0 feet msl. On this map, groundwater moves from the northwestern portion of the site radially toward surface water bodies (Marumsco Creek, Occoquan Bay, and Belmont Bay). Figure 2-17 provides a similar representation for wells whose screen midpoint falls between 0 and –10 feet msl. Figure 2-18 presents contours constructed based on groundwater elevations for wells with screen midpoint between –10 to –20 feet msl. Radial groundwater flow is also apparent based on these contours. However, groundwater contours in the area just north of the Main Compound area have an unusual bend. This bend could be accounted for if a zone of high hydraulic conductivity exists in a north-south orientation in the area of MW-57. A high-conductivity zone in this area would cause groundwater contours to be refracted from surrounding low-conductivity areas toward the MW-57 area. Another explanation for such curvature of groundwater contours in this area is the presence of unconfined conditions at MW-57 and confined conditions in surrounding areas. Figure 2-19 presents groundwater contours based on groundwater elevations for wells whose screen midpoint falls between –20 to –30 feet msl. Radial groundwater flow is apparent based on these contours. On these groundwater contour maps, there is very little interaction between small surface water features (such as the Main Ditch) and groundwater due to the presence of a confining clay unit that separates water-bearing units from surface water bodies.

Because the nature of aquifer is not simple, nor is it well defined, either of the above interpretations of groundwater flow at WRF may represent the actual groundwater flow condition. However, both interpretations indicate that, on a larger scale, radial groundwater flow is present from upland areas toward regional discharge points such as Occoquan Bay, Marumsco Creek, and Belmont Bay.

2.6 SUMMARY

The hydrogeology at the WRF is characterized by complex stratigraphy and variable topography. Therefore, these factors are important in determining aquifer conditions and groundwater flow patterns

beneath the site. The geologic materials beneath the site are a heterogeneous mixture of clay, silt, sand, and gravel. Porous, water-bearing units were deposited as discreet zones or lenses while clay layers appear to have been deposited as more continuous units. Due to heterogeneity, the permeability of subsurface materials changes dramatically from point to point beneath the site. Because these small-scale changes can not be delineated with the available data, the degree of hydraulic connection between water-bearing units is not known. Therefore, both unconfined and confined conditions may exist beneath the site. As a result, two interpretations of groundwater flow have been presented here, one that assumes primarily unconfined conditions and one that assumes confined conditions. These two interpretations of groundwater flow depend on the degree of hydraulic connection between water-bearing units. To define the degree of hydraulic connection between water bearing units at the site, a higher level of data is required than is currently available. Additional lithologic data would be required to determine whether water-bearing units are continuous or discreet. In addition, to define the hydraulic character of these water-bearing units, wells must be installed and carefully screened in the water-bearing unit of interest only to obtain groundwater elevations that are reflective of the hydraulic character of the aquifer material.

The level of data currently available for the site allows a reasonable estimate of the pattern of regional groundwater flow at the site. Water levels in the shallow aquifer system appear to be controlled by the nearby, local base level of Occoquan Bay, which is a regional discharge point for shallow groundwater. Groundwater moves radially from upland recharge areas north and northwest of the site toward Marumsco Creek, Occoquan Bay, and Belmont Bay.

The interaction between the Main Ditch and groundwater is difficult to assess with available well data. It is expected that over its course across the site property, the Main Ditch both loses and gains water depending on the underlying hydrogeologic unit and its degree of hydraulic connection with the Main Ditch. However, the composite water level map is drawn to show effluent conditions throughout its length to account for the possibility of shallow groundwater discharge from the subsurface to the ditch. There is a strong possibility, however, that in areas where the ditch flows across surface clay units, there is little interaction between groundwater and the ditch.

2.7 SITE HISTORY

WRF occupies approximately 579 acres of land (USAEC, 1995b). It is bounded on the south and east by the Occoquan and Belmont Bays. The facility is bounded on the west by the Marumsco National Wildlife Refuge and physically by the Marumsco Creek. The entrance to WRF is located on Dawson Beach Road, east of U.S. Route 1. Residential, commercial, and industrial areas are located north of WRF.

In 1952, the property was assigned to the U.S. Army Command and Administrative Communications Agency and designated as the Army Transmitting Station. In 1962, the Station was reassigned to the U.S. Army Continental United States (CONUS) Regional Communications Command and redesignated as the East Coast Radio Transmitting Station. In 1965, the Station was placed under the U.S. Army Strategic Communications Command. The Station was inactive for one year, from July 1969 to July 1970, before the U.S. Army Mobility Equipment Research and Development Center (MERDC) administered the Station. During that time, seven acres reserved for housing were transferred to Fort Belvoir, which is located approximately six miles northeast of the WRF. In 1971, a consolidation of U.S. Army Materiel Command (USAMC) nuclear weapons effects research and test activities resulted in the transfer of 642 acres of the land to Harry Diamond Laboratories of Adelphi, Maryland. The site was designated as the Woodbridge Research Facility and in August 1973, 63 acres of the installation in the vicinity of Marumsco Creek were transferred to the U.S. Department of the Interior for use as a park and wildlife refuge (Marumsco National Wildlife Refuge); and the Electromagnetic Effects Laboratory was physically relocated from Fort Belvoir to WRF.

In 1991, the Defense Base Realignment and Closure Commission recommended realignment of the Army activities being conducted at WRF. In October 1992, Harry Diamond Laboratory was absorbed into the Army Research Laboratory in Adelphi, Maryland, and most activities were relocated to the Adelphi Laboratory Center, in Adelphi, Maryland. The WRF was closed as an active Army facility on September 16, 1994. The property will be transferred to the USFWS for use as a wildlife refuge sometime in the near future.

WRF has 49 sites of concern identified as AREEs. These 49 AREEs are listed in Table 2-2 and shown in Figures 2-20 and 2-21. Previous investigations have shown that contaminated media exists at many of these AREEs. AREE 11 is located on the north side of Building 202, and includes the site of a now-removed oil/water separator, a now-removed vehicle washrack, and a now-removed "PCB Hot Spot" that was found in 1993 in a ditch north of Locust Road. AREE 17 is the location of a hydraulic oil spill that occurred in 1989. AREE 22 is the entirety of the Main Ditch. OU3 includes those portions of these three AREEs.

2.8 PREVIOUS INVESTIGATIONS

This section summarizes the results from previous investigations focusing on OU3, (the Main Ditch and the portions of AREE 11 and AREE 17 which are outside and north of the fenced Main Compound Area). The area of the ditch directly north of the Main Facility Compound received runoff from the former oil/water separator and the former washrack, and PCBs are the primary chemical of concern. The upper-most reaches of the drainage ditch have received runoff from on-site and off-site sources.

2.8.1 Virginia Department of Environment, Bioaccumulation Initiative

In March 1993, the VADEQ collected sediment and storm water runoff samples from the portion of the ditch which is topographically downgradient from the Main Compound (which includes runoff from the former oil/water separator and former washrack). This sampling was done as part of Virginia's Coastal Zone Management Program (NOAA, 1994). The sample locations are presented in Figure 2-22. The samples were analyzed for target compound list (TCL), volatile organic compounds (VOCs), TCL semi-volatile organic compounds (SVOCs), pesticides/PCBs, and target analyte list (TAL) metals.

2.8.1.1 Summary of Results

PCB-1260 was detected in the sediment and storm water runoff samples. The concentration of PCB-1260 in sediments ranged from 4.8 µg/g to 100 µg/g. The highest detected concentration was located at sample location WRF08B, which was collected along the drainage swale immediately downgradient from the former oil/water separator. The source of the contamination is most likely runoff from the former oil/water separator and the former washrack. PCB-1260 was also detected in one storm water sample (WRF08) at a concentration of 1.50 µg/L and was collected at the culvert outfall as shown on Figure 2-22.

2.8.2 USAEC Site Inspection, 1993 and Supplemental Site Inspection, 1994

Three sediment and two surface water samples (sample designations 22SE01, 22SE02/22SW02, and 22SE04/22SW04) were collected during the 1993 Site Inspection (SI) and in the OU3 area. Sample locations are presented on Figure 2-22. The samples were collected after a storm event to characterize the potential for contaminant migration from potential source areas to the Main Ditch. The samples were analyzed for TPH. In addition, one sediment sample (11SE0101) was collected from the outfall area associated with AREE 11 (Former Oil/Water Separator, north of Building 202). The sample was analyzed for VOCs, SVOCs, TPH, and pesticides/PCBs. The sample location is presented on Figure 2-22.

2.8.2.1 Summary of Results

TPH was detected in two of the four sediment samples (22SE01 and 22SE02) at levels of 18.0 and 14.0 µg/g, respectively. PCB-1260 was detected in the sediment sample (11SE0101) collected from the outfall area at a concentration of 1,170 µg/g (USAEC, 1995b). Other compounds detected from this sample include: 1,4-dichlorozenzene (39.0 µg/g); 1,2-dichlorobenzene (8.60 µg/g); 1,2,4-trichlorobenzene (260 µg/g); and chlorobenzene (1.60 µg/g).

2.8.3 USAEC Removal Action, 1995

A removal action was initiated in the summer of 1995 in which the oil/water separator, washrack, soils around the excavated pits, and contaminated soils along the outfall ditch were removed. An illustration of this ditch excavation area is presented in Figure 2-21. During the removal action excavation, a water-bearing sand lens exhibiting a visible oil sheen was encountered. A water sample

was collected from this zone and analyzed for PCBs and TPH. PCBs were detected at a concentration of 6.4 µg/L and the estimated TPH concentration was 220 µg/L (USAEC, 1995d). A pre-excavation soil sample was collected from the trench area and was analyzed for PCBs. The maximum PCB concentration was 16,000 µg/g (USAEC, 1995d). Hydropunch® samples were collected in downgradient locations to determine the extent of TPH contamination in groundwater. The Hydropunch® sample locations are not presented because the exact locations are not known. TPH was detected in all downgradient locations investigated, including the Main Ditch (AREE 22). The extent of the contamination was not determined. The suspected source areas for the TPH contamination are the former underground storage tanks (USTs) located on the east side of Building 202, the former washrack area, the former UST located on the north side of Building 202 (AREE 23b), and possibly the former oil/water separator and the former washrack.

2.9 USAEC REMEDIAL INVESTIGATION FOR OPERABLE UNIT THREE

This section presents sample results of the fieldwork portion of the RI, which was initiated in the late fall of 1995 and early winter of 1996 (USAEC, 1995b). The RI field effort consisted of two phases that ended in the late summer of 1996. The first section describes the samples collected from background locations. The remaining sections present sampling rationale, sampling locations, and analytical results from samples collected at OU3 for all media sampled.

2.9.1 USAEC REMEDIAL INVESTIGATION BACKGROUND SAMPLING

The following samples were collected from background locations near and within WRF: five surface soil samples (0-6 inches below ground surface [bgs]); three surface soil samples (0 to 2 feet bgs) and six subsurface soil samples (varying depths) collected from borings which were later converted to monitoring wells; two rounds of groundwater samples from four background monitoring wells; and five surface water and sediment samples. This section presents the results of the background analyses. The locations for on-site background samples are presented on Figure 2-23 and the locations for the surface water/sediment samples are presented in Figure 2-24.

2.9.1.1 Determination of Background Concentrations

A statistical analysis was performed for all sampled media, in order to determine if detected levels of inorganic compounds present at the site were representative of naturally occurring background levels.

Surface Soil

Five surface soil samples (RIBKSS1 through RIBKSS5) were collected from on-site locations that were upgradient and/or unaffected by past site activities. The locations of the surface soil samples are presented on Figure 2-23. These five background surface soil samples were analyzed for TCL VOCs, TCL SVOCs, pesticides/PCBs, PAHs, PCTs, TPH, and TAL metals. Inorganics detected in background surface soil samples are presented in Table 2-3. Organics detected in background surface soil samples are presented in Table 2-4.

Summary of Results. The following is a summary of the inorganics detected in the background surface soil samples. Aluminum was detected in all samples in a range of concentrations from 6,550 µg/g to 14,600 µg/g. Arsenic was detected once at 3.85 µg/g in RIBKSS1, but was not detected in the duplicate. Barium was detected in RIBKSS3 and RIBKSS5 at 67 µg/g, and 73.4 µg/g, respectively. Beryllium was detected in all samples except RIBKSS4, with a maximum detected concentration of 0.785 µg/g. Calcium was detected in all samples except RIBKSS1 with a maximum concentration of 1,020 µg/g. Chromium, cobalt, copper, and iron were detected in all samples with maximum detected concentrations of 26.7 µg/g, 12.7 µg/g, 12/6 µg/g, and 23,900 µg/g, respectively. Lead was detected in all samples except RIBKSS2 with a maximum detected concentration of 22.4 µg/g. Magnesium, manganese, nickel, potassium, sodium, vanadium, and zinc were also detected in all samples with maximum detected concentrations of 1,700 µg/g, 677 µg/g, 8.98 µg/g, 597 µg/g, 487 µg/g, 47.1 µg/g, and 40.4 µg/g, respectively. Selenium was detected in one sample (RIBKSS3) at 14.2 µg/g.

Four organic compounds, benzo(b)fluoranthene, benzo(k)fluoranthene, flouranthene, and indeno(1,2,3-cd)pyrene, were detected in all background surface soil samples at maximum concentrations of 0.01 µg/g (RIBKSS3), 0.005 µg/g (RIBKSS3 and RIBKSS5), 0.018 µg/g (RIBKSS3), and 0.01 µg/g (RIBKSS4), respectively. Aldrin and methylene chloride were detected at one location at concentrations of 0.003 µg/g (RIBKSS2), and 0.02 µg/g (RIBKSS5), respectively. Anthracene and benzo (g,h,i) perylene were detected at maximum concentrations of 0.028 µg/g and 0.011 µg/g, respectively in samples collected from RIBKSS3, RIBKSS4, and RIBKSS5. Benzo(a)anthrancene, benz(a)pyrene, and pyrene were detected in all samples except RIBKSS1, with maximum concentrations of 0.005 µg/g, 0.008 µg/g, and 0.023 µg/g, respectively. Phenanthrene was detected in RIBKSS1 and RIBKSS2 with a maximum concentration of 0.347 µg/g in RIBKSS1.

Subsurface Soil

Subsurface Soil samples were collected from borings in which background monitoring wells MW-52, MW-53, and MW-54 were installed for the RI. The locations for these samples are shown on Figure 2-23. The samples were collected from 0 to 2 feet bgs and every 5 feet thereafter to the water table. All subsurface soil samples were analyzed for TCL VOCs, TCL SVOCs, pesticides/PCBs, TAL metals, and polychlorinated terphynles (PCTs). The soil samples collected from these background locations were grouped into two categories for risk assessment purposes.

The first grouping (which consists of three samples) were samples collected from 0 to 2 feet bgs. These data were combined with the five background surface soil samples to bolster the data set for background surface soil. Therefore, a total of eight surface soil samples were used to statistically determine which site surface soil concentrations were within background levels. Detected compounds for this set of subsurface soil samples is given in Table 2-5.

The second grouping from the subsurface soil samples consisted of samples collected at depths below 2 feet bgs. The six samples collected from 2 feet bgs to the water table were grouped for the purposes of determining which compounds detected in on-site samples were within background levels. Detected compounds for this set of subsurface soil samples is presented in Table 2-6.

Summary of Results The following inorganics were detected in all subsurface soil samples from 0 to 2 feet bgs (the maximum concentration detected is also listed): aluminum 22,000 µg/g; beryllium, 0.814 µg/g; calcium, 1,150 µg/g; chromium, 31.3 µg/g; cobalt, 16.6 µg/g; copper, 11.5 µg/g; iron, 28,100 µg/g; magnesium, 2610 µg/g, manganese, 875 µg/g; nickel, 11.9 µg/g; potassium, 936 µg/g; sodium, 453 µg/g; vanadium, 58.9 µg/g; and zinc, 43.9 µg/g. Barium and lead were detected in MW-53 and MW-54 soils from 0 to 2 feet bgs with maximum concentrations of 92.4 µg/g and 17.7 µg/g, respectively. Arsenic was detected in MW-53 from 0 to 2 feet bgs at 3.24 µg/g. Selenium was detected in the MW-54 subsurface 0 to 2 feet bgs soil sample at 13 µg/g. Bis (2-ethylhexyl)phthalate was the only organic to be detected in subsurface soil samples from 0 to 2 feet bgs. It was detected in MW-53 and MW-54 at 0.18 µg/g and 0.50 µg/g, respectively.

The following inorganics were also detected in most subsurface soil samples collected from 2 feet bgs to the water table (maximum detected concentration is also listed); aluminum, 18,200 µg/g; barium, 93 µg/g; beryllium, 1.02 µg/g; calcium, 911 µg/g; chromium, 25 µg/g; cobalt, 13.9 µg/g copper, 19.1 µg/g; iron, 27,800 µg/g, magnesium, 3,700 µg/g; manganese, 617 µg/g; nickel, 20.9 µg/g; potassium, 624 µg/g; sodium, 939 µg/g; vanadium, 60.3 µg/g, and zinc, 55.6 µg/g. No organic compounds were detected in subsurface soil samples from 2 feet bgs to the water table.

Sediment

Five sediment samples (RISDBK1 through RISDBK5) were collected from Mason Neck Wildlife Refuge, which is located east of WRF. Since Mason Neck is located across the Belmont Bay from WRF, it has not been impacted from past activities related to WRF. The samples were collected from 0 to 6 inches and were analyzed for TCL VOCs, TCL SVOCs, pesticides/PCBs, PAHs, TAL metals, PCTs, TPH, grain size distribution, and total organic carbon (TOC). Background sediment samples locations

are presented in Figure 2-24. Table 2-7 and 2-8 present the inorganic and organic compounds detected in the background sediment samples, respectively.

Summary of Results. The following inorganics were detected in all sediment background samples (maximum detected concentration is also listed): aluminum, 16,900 µg/g; beryllium, 1.38 µg/g; calcium, 6,000 µg/g; chromium, 33.7 µg/g; cobalt, 21.4 µg/g; copper, 44.4 µg/g; iron, 36,500 µg/g; magnesium, 3,740 µg/g; manganese, 1,690 µg/g; nickel, 30.3 µg/g; potassium, 2,120 µg/g; sodium, 1,710 µg/g; vanadium, 54.1 µg/g; and zinc, 168 µg/g. In addition, barium was detected in RISDSK1 at 175 µg/g and lead was detected in four of the background sediment samples with a maximum detected concentration of 42.2 µg/g.

Several PAHs, including anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(g,h,i)perylene, benzo(k)fluoranthene, dibenz(a,h)anthracene, fluoranthene, indeno(1,2,3-cd)pyrene, and pyrene were detected in most if not all background sediment samples at low levels (<1 µg/g). In addition, 1-methyinapthalene, benzo(b)fluoranthene, and fluorene were detected in three background sediment samples with maximum detected concentrations of 1.14 µg/g, 0.083 µg/g, and 0.355 µg/g, respectively. Acenaphthene and methylene chloride were detected in two background samples with a maximum detected concentrations of 1.27 µg/g and 0.061 µg/g, respectively. Napthalene was detected in RISDBK3 at 0.636 µg/g.

Surface Water

At each sediment sample location, a surface water sample was also collected. Surface water samples were collected from 0-6 inches below the water surface and were analyzed for TCL VOCs, TCL SVOCs, pesticides/PCBs, PAHs, TAL metals, PCTs, TPH, total suspended solids, alkalinity, and hardness. Background surface water samples locations are presented in Figure 2-24. Inorganic compounds detected in the surface water samples are given in Table 2-9.

Summary of Results. The following inorganics were detected in all surface water background samples (maximum detected concentration is also listed): aluminum 1,930 µg/L; barium 41.8 µg/L; calcium 22,200 µg/L; iron 2,510 µg/L; lead 1.9 µg/L; magnesium 7,500 g/L; manganese 303 µg/L; potassium 3,670 µg/L; and sodium 16,500 µg/L. The concentrations detected in the surface water samples did not vary much from sample to sample. Arsenic was detected in RISWBK1 at 1.4 µg/L and chromium was detected in RISWBK2 at 10.8 µg/L. No organic compounds were detected in background surface water samples.

Groundwater

Two rounds of groundwater samples were collected from shallow monitoring wells MW-52, MW-53, MW-54, and deep monitoring well MW-63 for a total of eight samples. All groundwater samples were analyzed for TCL VOCs, TCL SVOCs, pesticides/PCBs, PCTs (first round only), TAL metals, PAHs, and TPH. The samples collected from MW-52, MW-53, MW-54, and MW-63 were used to characterize inorganic background concentrations for groundwater. Organic compounds detected in the background groundwater samples were not used to establish an organic background baseline. Refer to Figure 2-23 for the location of the background monitoring wells. Table 2-10 is a summary of the inorganic compounds detected in the background groundwater samples. Table 2-11 is a summary of the organic detections reported by the laboratory for the background groundwater samples.

Summary of Results. The following inorganics (maximum concentration detected is also listed) were detected in most if not all background groundwater samples: aluminum, 12,500 µg/L; barium, 107 µg/L; calcium, 12,800 µg/L, iron, 9,620 µg/L, magnesium, 7,720 µg/L; manganese, 354 µg/L; potassium, 20,900 µg/L; and sodium, 44,300 µg/L. Arsenic was detected in wells MW-53 and MW-63 with a maximum detected concentration of 6.9 µg/L, Cadmium was detected in wells MW-53, MW-54, and MW-63 with a maximum detected concentration of 0.8 µg/L. Chromium and copper were detected at 22.3 µg/L and 8.9 µg/L, respectively in MW-53. Lead was detected in MW-53 with a maximum concentration of 6.3 µg/L. Nickel was detected at 18.4 µg/L in MW-52. Selenium was detected in all wells except MW-54 (maximum concentration of 4.2 µg/L) during the first round of sampling but was not detected in samples

collected during the Round 2 sampling. Thallium was detected in MW-53 at 0.1 µg/L in the Round 1 sample but was not detected in the Round 2 sample. Vanadium was detected in MW-63 for samples collected from both sampling rounds and in well MW-53 in the sample collected during Round 1. The maximum detected concentration of vanadium in the background samples was 31.4 µg/L (MW-63). Zinc was detected in samples from wells MW-52 and MW-53 during the Round 1 sampling and in the MW-52 sampling during Round 2 with a maximum detected concentration of 46.0 µg/L.

Monitoring well MW-63 was installed as a deep background monitoring well for the RI. However, elevated levels of organic compounds were unexpectedly detected in the well. An additional AREE (AREE 41, Old Homestead) was created to further evaluate an old homestead area that may be the source for the contamination detected in this well. Inorganic results from MW-63 were used to develop site specific background concentrations in groundwater. The organic compounds that were detected in groundwater were not used to establish a background organic database. The following organic compounds were detected in groundwater samples collected from MW-63 during Round 1: 1-methylnapthalene (119 µg/L); 2-methylnapthalene (80.5 µg/L); acenaphthene (11.0 µg/L); acenapthylene (6.34 µg/L); endosulfan B (0.021 µg/L); endosulfan sulfate (0.027 µg/L); endrin (0.022 µg/L); ethybenzene (13 µg/L); fluoranthene (0.063 µg/L); fluorene (3.2 µg/L); napthalene (30 µg/L); phenanthrene (8.69 µg/L); pyrene (0.158 µg/L); toluene (5.2 µg/L); TPH, as diesel (900 µg/L): TPH, as gas (740 µg/L); and xylenes (54 µg/L). Organic compounds (and their respective maximum concentrations) detected during Round 2 sampling are as follows: 1-methylnapthalene (101 µg/L); 2-methylnapthalene (79.3 µg/L and 78.8 µg/L) in MW-63 duplicate; acenapthene (4.17 µg/L and 8.27 µg/L) in MW-63 duplicate; acenapthylene (3.01 µg/L); anthracene (2.00 µg/L); BHC.B (0.017 µg/L); BHC.G (0.098 µg/L); dieidrin (0.026 µg/L) and 0.018 µg/L in MW-63 duplicate; dimethyl phthaleate (3.90 g/L in MW-63 duplicate); endosulfan sulfate (0.019 µg/L); ethylbenzene (5.30 µg/L) and 5.20 µg/L in MW-63 duplicate; fluoranthene (0.069 µg/L) and 2.01 µg/L in MW-63 duplicate; phenanthrene (6.43 µg/L) and 6.35 µg/L in MW-63 duplicate pyrene (0.162 µg/L) and 0.137 µg/L in MW-63 duplicate; tolunene (2.30 µg/L) and 2.10 µg/L in MW-63 duplicate; TPH, as diesel (1,140 µg/L) and 1,130 µg/L in MW-63 duplicate; TPH, as gas (558 µg/L) and 538 µg/L in MW-63 duplicate; and xylenes (32.0 µg/L) and 31.0 µg/L: in MW-63 duplicate.

Inorganics compounds detected in Round 1 from MW-63 are as follows: aluminum (635 µg/L); arsenic (1.6 µg/L); barium (30.8 µg/L); calcium (24,300 µg/L); iron (433 µg/L); magnesium (3,580 µg/L); manganese (12 µg/L); potassium (14,000 µg/L); selenium (2.7 µg/L); sodium (41,300 µg/L); and vanadium (12.3 µg/L). The following inorganic compounds were detected in the groundwater sample and duplicate collected from MW-63 during Round 2; aluminum (780 µg/L) and 514 µg/L in the MW-63 duplicate; arsenic (6.9 µg/L) and 6.5 µg/L in the sample collected from the MW-63 duplicate; barium (30.3 µg/L) and 27.2 µg/L in the MW-63 duplicate; cadmium (0.2 µg/L in the MW-63 duplicate); calcium (42,800 µg/L) and 41,600 µg/L in the MW-63 duplicate; iron (532 µg/L) and 209 µg/L in the MW-63 duplicate; lead (1.2 µg/L) in the MW-63 duplicate; magnesium (225 µg/L) and 157 µg/L in the MW-63 duplicate; manganese (10.8 µg/L) potassium (20,900 µg/L) and 20,300 µg/L in the MW-63 duplicate; sodium (44,300 µg/L) and 42,700 µg/L in the MW-63 duplicate and vanadium (31.4 µg/L) and 28.2 µg/L in the MW-63 duplicate.

Two organic compounds were detected in background monitoring well MW-52. Anthracene was detected at 0.113 µg/L in the MW-52 Round 1 sample but was not detected in the Round 2 sample. Endosulfan sulfate was detected in MW-52 Round 1 and 2 samples at concentrations of 0.146 µg/L and 0.138 µg/L, respectively. No organic compounds were detected in MW-53 and MW-54 groundwater samples.

2.10 OPERABLE UNIT THREE INVESTIGATIONS

OU3 includes AREE 22 (the Main Ditch), the portion of AREE 11 that is located north and outside of the Main Compound, and also the portion of AREE 17 that is located north and outside the

Main Compound. The boundaries of OU3 are illustrated on Figure 2-20. The primary media evaluated as part of the FFS for OU3 was the sediment and surface water samples collected from the Main Ditch, north of Charlie Road and the fish tissue samples collected from areas downgradient from the Main Compound in the Main Ditch (refer to Figure 2-22). The area of the ditch directly north of the Main Compound received runoff from the former oil/water separator and the former washrack, and PCBs are the primary chemical of concern. The upper-most reaches of the Main Ditch have received runoff from on-site and off-site sources. In addition, the small area north of the Main Compound and directly east and west of the 1995 PCB excavation trench (the portions of AREEs 11 and 17 discussed above), refer to Figure 2-21, was investigated through subsurface soil sampling of five soil borings (converted to monitoring wells MW-55, MW-56, MW-57, MW-58, and MW-85), three additional soil borings (RISB3, RISB4, and RISB5), three surface soil samples (RISS51, RISS52, and RISS53), and seven groundwater samples (five of which were collected from monitoring wells MW-55 through MW-58, MW-85, and two deep wells installed during the RI, MW-62 and MW-84. Sample locations for the soil borings, surface soil samples, and monitoring wells are illustrated on Figure 2-25. Surface water and sediment samples are presented in Figure 2-26.

2.10.1 AREEs 11 and 17 (Portions outside the Main Compound)

Surface Soil

Three surface soil samples (RISS51 through RISS53) were collected in the grassy area between the Main Compound and the Main Ditch to evaluate if run-off from the former oil/water separator and the former washrack had impacted surface soil. One sample was collected from the eastern side of the 1995 PCB excavation ditch and two from the western side of the 1995 PCB excavation ditch. Surface soil samples were analyzed for TCL VOCs, TCL SVOCs, pesticides/PCBs, TAL metals, PAHs, and TPH. Analytical results of these samples are summarized in Table 2-12.

Two inorganic compounds were detected at concentrations exceeding site background. Barium was detected in both RISS51 and RISS52 at concentrations of 98.0 µg/g and 95.4 µg/g, respectively. The site background concentration for barium is 92.4 µg/g. Zinc was detected in the same samples at concentrations of 49.2 µg/g and 49.4 µg/g, respectively. The site background concentration for zinc is 43.9 µg/g. PCB-1260 was detected in RISS52 and RISS53 above the risk based concentration (RBC) of 0.083 µg/g at concentrations of 0.123 µg/g and 0.149 µg/g, respectively.

Subsurface Soil

Three soil borings (RISB3 through RISB5) were drilled to evaluate the extent of contamination in the area near the 1995 PCB removal action. One soil boring, RISB3, was drilled adjacent to the head wall of the drainage ditch immediately north of Locust Road, where the culvert crosses under the road. Soil boring RISB4 was drilled adjacent to the sidewall of the 1995 PCB excavation ditch, to further evaluate the area where residual PCB-1260 was detected at a concentration of 210 µg/g. Soil boring RISB5 was drilled between the 1995 PCB excavation ditch and monitoring wells MW-56 and MW-62 to evaluate potential subsurface soil contamination within this area. In addition, subsurface soil samples were collected during the installation of monitoring wells MW-55, MW-56, MW-57, MW-58, and MW-85. Analytical results of these samples are summarized in Table 2-12. Two deep monitoring wells, MW-62 and MW-84 were drilled using the mud-rotary drilling techniques and, therefore, were not sampled.

Arsenic was detected at a concentration of 1.55 µg/g in the shallow subsurface (0 to 20 feet bgs) soil samples collected from MW-56. The WRF site background concentration for arsenic is non-detect. Barium was detected above the site background concentration in two samples, MW-56 and MW-57, (0 to 2 feet bgs) at respective concentrations of 89.6 µg/g and 86.6 µg/g. The site background concentration for barium is 73.8 µg/g. Calcium was detected in several shallow subsurface soil samples above the site background concentration of 454 µg/g. The shallow subsurface soil sample collected from MW-85 had a concentration of copper of 28.6 µg/g. The site background concentration for copper is 16.9 µg/g. The following 0 to 2 feet bgs soil samples had concentrations of lead exceeding the site background concentration of 11.8 µg/g: MW-55 (26.8 µg/g); MW-57 (20.3 µg/g); MW-85 (25.3 µg/g); and RISB3 (26.7 µg/g). The 0 to 2 feet sample collected from the MW-58 boring had a manganese concentration of 788 µg/g. All other shallow subsurface soil sample manganese concentrations from this area were below

the site background concentration of 617 µg/g. Selenium was detected at a concentration of 15.3 µg/g in the shallow subsurface soil sample collected from RISB3. The site background concentration for selenium is non-detect. Several soil samples (0 to 2 feet bgs) had concentrations of vanadium exceeding the site background concentration of 25.8 µg/g. These samples include: MW-55 (34.0 µg/g); MW-57 (30.7µg/g); MW-85 (33.1µg/g); RISB3 (37.6 µg/g); RISB4 (35.1 µg/g) and RISB5 (26.1 µg/g).

The only organic compound detected above its RBC in shallow subsurface (0 to 2 feet bgs) was PCB-1260. This compound was detected in several soil samples. These include: MW-55 (0.29 µg/g); MW-57 (0.39 µg/g); MW-85 (0.339 µg/g); RISB3 (0.70 µg/g); RISB4 (0.48 µg/g); and RISB5 (0.12 µg/g). The RBC for PCB-1260 is 0.083 µg/g (this value is for carcinogenic RBCs).

Aluminum was detected in the 15 to 17 feet bgs sample collected from the MW-56 soil boring at a concentration of 18,500 µg/g. The maximum site background concentration for aluminum is 18,200 µg/g. Arsenic was detected in the 15 to 17 feet bgs sample from MW-56 at a concentration of 0.95 µg/g. The site background concentration for arsenic is non-detect. Four soil samples had concentrations of barium above the maximum site background concentration of 73.8 µg/g. These samples are as follows: MW-55 (12-14 feet bgs - 112 µg/g) and MW-55 (15 to 17 feet bgs - 88.6 µg/g); MW-56 (15 to 17 feet bgs - 79.7 µg/g); and MW-57 (5-7 feet bgs - 77.3 µg/g). Beryllium was detected in both the 12-14 feet bgs and 15 to 17 feet bgs samples collected from the MW-55 soil boring at respective concentrations of 1.20 µg/g and 1.29 µg/g. The site background concentration for beryllium is 1.02 µg/g. Calcium was detected at concentrations exceeding the site background concentration of 454 µg/g in soil samples collected from the following borings: MW-55 (12-14 feet bgs and 15 to 17 feet bgs) and MW-56 (10-12 feet bgs and 15 to 17 feet bgs). Chromium was detected above the site background concentration of 25.0 µg/g in MW-55 (15 to 17 feet bgs) at a concentration of 30.3 µg/g and in MW-56 (15 to 17 feet bgs) at a concentration of 26.6 µg/g. Cobalt was detected at a concentration of 27.8 µg/g in the 15 to 17 feet bgs sample collected from MW-55. The WRF site background maximum concentration for cobalt is 13.9 µg/g. MW-55 soil samples contained concentrations of copper (12-14 feet bgs - 23.1 µg/g) and 15 to 17 feet bgs - 32.1 µg/g) that exceeded the site background concentration of 16.9 µg/g. Lead concentrations exceeded the WRF site background maximum concentration of 11.8 µg/g in samples collected from MW-55 (12-14 feet bgs) and MW-56 (15 to 17 feet bgs) at respective concentrations of 11.9 µg/g and 13.6 µg/g. Magnesium exceeded the WRF site background maximum concentration of 3,700 µg/g in MW-55 (15 to 17 feet bgs) at a concentration of 3,950 µg/g. Nickel (site background concentration of 17.9 µg/g) was detected in the 12-14 feet bgs and 15 to 17 feet bgs soil samples collected from MW-55 at concentrations of 20.3 µg/g and 36.0 µg/g, respectively. Potassium was detected in MW-55 and MW-56 at concentrations greater than the site background concentration of 624 µg/g. Selenium was detected at concentrations of 16.3 µg/g and 13.7 µg/g, respectively, in soil samples collected from RISB3 and RISB5. The WRF site background concentration for selenium is non-detect. Vanadium was detected in samples from MW-55, MW-56, MW-57, and RISB3 at concentrations exceeding the site background concentration of 25.8 µg/g.

No organic compounds were detected above their respective RBCs for subsurface samples collected from 2 feet bgs to the water table. The detected organic compounds are summarized on Table 2-12.

Groundwater

Five shallow monitoring wells, (MW-55 through MW-58 and MW-85) and two deep monitoring wells (MW-62 and MW-84) were installed in downgradient locations from suspected source areas associated with the former oil/water separator, former washrack, and Building 202 to evaluate the extent of subsurface soil and groundwater contamination. MW-55 was installed in an area where stressed vegetation has been observed. This area received surface water runoff from the former oil/water separator and is also where the hydraulic spill (AREE 17) occurred. A sand lens was encountered during the PCB removal action. It was believed to trend northwest from the former oil/water separator. Therefore, shallow monitoring well/soil boring MW-56 and deep monitoring well MW-62 were installed downgradient of the former oil/water separator, and were located to intercept the sand lens, if possible. Soil boring/monitoring well MW-57 was located adjacent to the drainage ditch to evaluate groundwater

quality prior to potential discharge to the Main Ditch. Soil borings/monitoring wells MW-58 and MW-85 were installed downgradient of the 1995 PCB excavation in order to determine if the soils and/or groundwater downgradient have been impacted by the contamination found during the excavation.

MW-84 was installed as a cluster well adjacent to MW-39 to evaluate water quality downgradient from the former oil/water separator, former washrack, and drum storage area. Existing monitoring well, MW-39, was installed as part of the Phase II SC, and was sampled during the RI (Round 1 sampling only) to evaluate groundwater quality downgradient of the drum storage area (AREE 12). Groundwater samples were analyzed for TCL VOCs, TCL SVOCs, pesticides/PCBs, TAL metals, PCTs (Round 1 only), PAHs, and TPH. Analytical results of these samples are summarized in Table 2-13.

Iron was detected above the WRF site background maximum concentration (9,620 µg/L) in six monitoring wells: MW-56 (17,200 µg/L); MW-57 (14,600 µg/L); MW-62 (18,000 µg/L); MW-56 Round 2 (15,800 µg/L); MW-57 Round 2 (15,000 µg/L); and MW-62 (15,300 µg/L). Manganese was detected above the WRF site background maximum concentration of 354 µg/L in the following monitoring wells: MW-56 (399 µg/L); MW-57 (411 µg/L); MW-62 (562 µg/L); MW-85 (471 µg/L); MW-85 Dup (493 µg/L); MW-56 Round 2 (370 µg/L); MW-57 Round 2 (434 µg/L); and MW-62 Round 2 (494 µg/L). Zinc was detected in the following samples collected from monitoring wells outside the Main Compound: MW-39 (205 µg/L) MW-39 Dup (226 µg/L); MW-55 (182 µg/L); MW-85 (94.5 µg/L) and MW-55 Round 2 (119 µg/L). The site background for zinc is 46 µg/L.

Dieldrin was detected in MW-55 at a concentration of 0.009 µg/L. The RBC for dieldrin is 0.0042 µg/L. Phenanthrene was detected in MW-84 Round 2 at a concentration of 0.715 µg/L. No PCBs were detected in groundwater samples collected from this area.

Summary of Results

Surface soil samples collected north of the Main Compound Area contained concentrations barium and zinc above WRF site background concentrations. PCB-1260 was detected above the RBC of 0.083 µg/g in RISS52 and RISS53.

Shallow subsurface soil samples contained several metals above site background concentrations. Arsenic was detected in the 0 to 2 feet bgs sample collected from MW-56 at a concentration of 1.55 µg/g. Barium, calcium, copper, lead, manganese, selenium, and vanadium were detected at levels exceeding their respective maximum site background concentrations. PCB-1260 was detected in shallow subsurface soil samples from MW-55, MW-57 MW-85, RISB3, RISB4, and RISB5 at concentrations above the PCB-1260.

Deeper subsurface soil samples contained the following metals at concentrations exceeding their respective site background concentrations: aluminum; arsenic; beryllium; calcium; chromium; cobalt; lead; magnesium; nickel; potassium; selenium; and vanadium.

Groundwater samples collected from this area contained metals concentrations exceeding site background in iron, manganese, and zinc. Dieldrin and phenanthrene were detected in MW-55 and MW-85, respectively at relatively low concentrations.

2.10.2 Operable Unit Three Surface Water/Sediment Sampling

Surface water and sediment samples were collected as part of this RI. A total of 45 samples were collected throughout the WRF, and 16 samples (RISW/RISD24, and RISW/RISD26 through RISW/RISD40) were collected from OU3 at locations illustrated on Figure 2-26. Three additional sediment samples were collected from sample location RISD32 to evaluate the vertical extent of PCB contamination at that location. The following samples were collected RISD32a at 0.5 to 1 feet bgs; RISD32b at 1.5 to 2.0 feet bgs; and RISD32c at 2.5 to 3.0 feet bgs. The surface water/sediment samples were analyzed for TCL VOCs, TCL SVOCs, PAHs, pesticides/PCBs, PCTs, TPH, TAL metals, grain size distribution (sediment only), and total organic carbon (sediment only). The vertical profile samples (RISD32a, b, and c) were analyzed for PCBs. A summary of detected compounds for sediment and surface water is given in Tables 2-14 and 2-15, respectively.

Summary of Results

Inorganic compounds detected in OU3 sediment samples as well as site-wide samples are presented in Figure 2-27. Total PCBs, TPH, total pesticides, and total PAHs detected in sediment samples for OU3 as well as site-wide concentrations are presented in Figure 2-28. Total pesticides and inorganic compounds (detected above site background) in surface water are shown on Figure 2-29.

PCB-1260 was detected at concentrations ranging form 6.04 µg/g at location RISD32 to 0.043 µg/g at location RISD35. As noted above, sample RISD32 (collected at 0 feet bgs) contained 6.04 µg/g of PCB-1260. Samples RISD32a, RISD32b, and RISD32c collected at 0.5 feet bgs, 1.5 feet bgs, and 2.5 feet bgs, respectively, contained concentrations of 0.072 µg/g, 0.161 µg/g, and 0.031 µg/g, PCB-1260. The area where PCB was detected is topographically downgradient from the former oil/water separator and the former washrack. The results of the vertical profile indicate that PCB concentrations are diminishing with depth.

Several PAHs were detected in sediment samples including 1-methylnaphthalene, 2-methylnaphthalene, acenaphthene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, benzoic acid, chrysene, dibenzo(a,h)anthracene, flouranthene, flourene, indeno(1,2,3-cd)pyrene, naphthalene, phenanthrene, and pyrene. The WRF is located in a highly urbanized area and the PAHs are attributed to its regional location.

The pesticides, chlordane (total), alpha-chlordane, gamma-chlordane, and DDD were detected at four of the ten locations sampled. Chlordane (total) was detected in samples RISD28 and RISD29, at 0.263 µg/g and 0.041 µg/g, respectively. Of the 0.263 µg/g total chlordane detected in RISD28, 0.021 µg/g was alpha-chlordane and 0.03 µg/g was gamma-chlordane. Alpha-chlordane and gamma-chlordane were also detected at sample location RISD27 at concentrations of 0.016 µg/g and 0.022 µg/g, respectively. DDD was detected a sample location RISD27 and RISD35 at concentrations of 0.016 µg/g and 0.024 µg/g, respectively. It is assumed that their presence is due to past pesticide use and possibly migration from off-site sources. However, it is not completely understood why the pesticides would occur specifically at these locations and not at other locations in the ditch.

TPH (as diesel) was detected at low levels (below the VADEQ Action Level of 100 µg/g) at three sample locations: RISD26, RISD33, and RISD34. Sample location RISD26 is located topographically downgradient from the former UST at Building 101, the most likely source area for the TPH detected at this location. The source for the TPH detected at sample locations RISD33 and RISD34 is most likely the former USTs and possibly the former oil/water separator located within the Main Compound.

Elevated levels of the following inorganic compounds were detected in surface water samples collected from the upper reaches of the drainage ditch: aluminum, arsenic, barium, copper, iron, lead, vanadium, and zinc. The elevated levels were detected in the northern portion of OU3. The samples were collected during a storm event and it is believed that the elevated levels of metals are a result of runoff from the area north of the facility where construction activities for the golf course were underway at the time of sample collection. The construction activities disturbed vegetation in the area and exposed soils. During the storm event, runoff came in contact with the exposed soils which are a source of naturally occurring metals. This is especially relevant because the surface water samples were unfiltered and sediments from the runoff likely increased the concentrations of metals detected in the surface water samples. Total pesticides and inorganic compounds detected above background concentrations in surface water are presented on Figure 2-29.

2.10.2.1 Summary of Investigations

The past investigations (including the Virginia Bioaccumulation Initiative and the SI) indicate that sediments in the lower portion of OU3, north of the Main Compound, are contaminated with PCB-1260. The highest concentrations of PCB-1260 were detected in samples collected for the Virginia Bioaccumulation Initiative and the SI. These samples were collected very close to the drainage swale and outfall area for the former oil/water separator and former washrack. PCB-1260 concentrations decrease with distance from this area and have not been detected downstream from sample location RISD36. PCBs have not been detected upstream from sample location RISD30 which is located

upstream from the drainage swale/outfall area north of the Main Compound. Therefore, the source of the contamination has been identified as the former oil/water separator and the former washrack where PCB-contaminated soils were disposed.

Pesticides are localized (with the exception of sample location RISD35) to the northern branches of Main Ditch near sediment sample locations RISD27 and RISD28. The source of the pesticides is assumed to be due to past use or disposal and possibly migration from off-site sources.

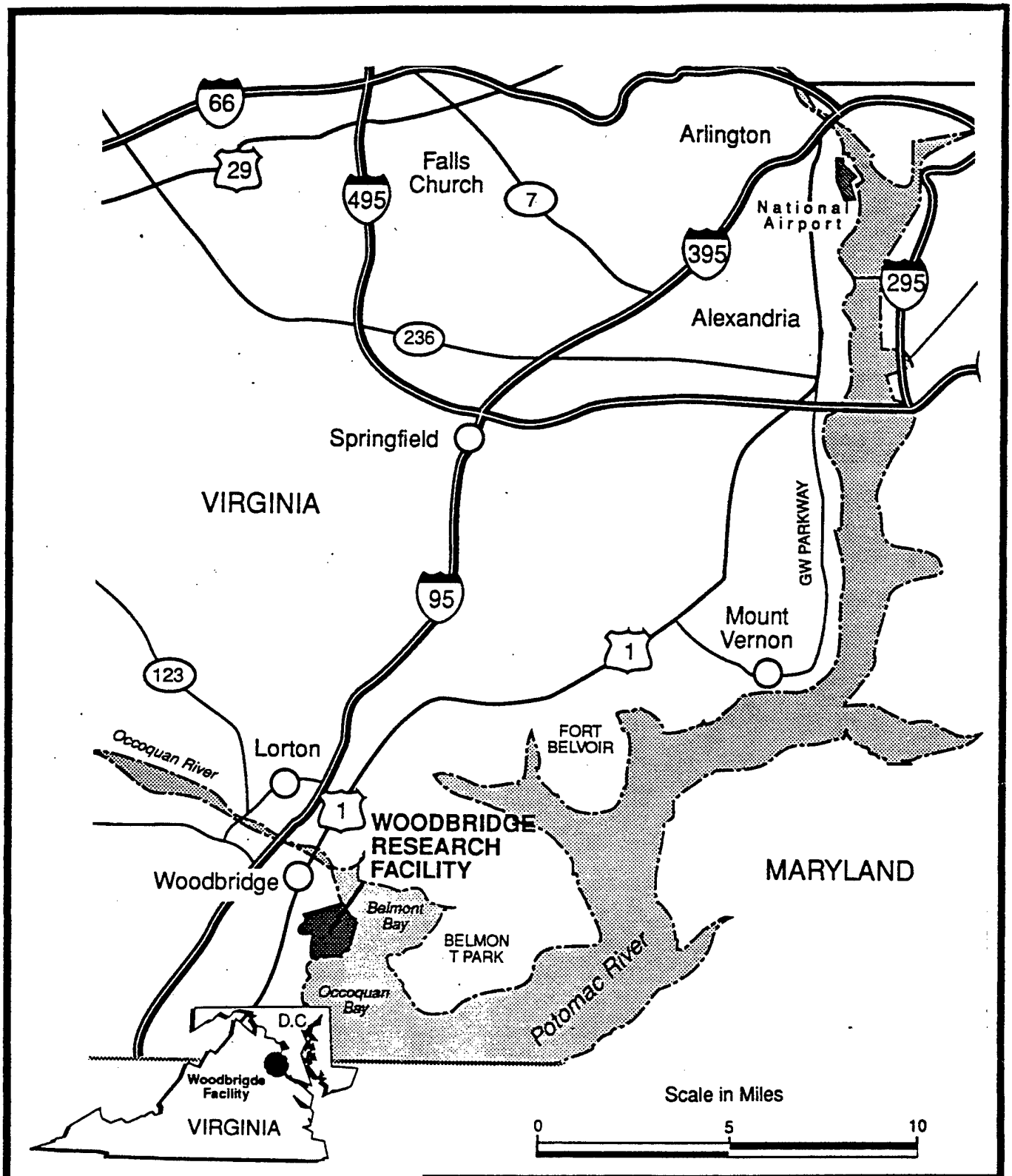
Several PAHs have been detected in sediments throughout OU3 as well as the rest of the site. The WRF is located in a highly urbanized area and the presence of PAHs in sediment may be due to its location in the urbanized setting. Other sources may be a result of runoff from areas where these compounds accumulated during past operational and disposal activities associated with the site.

Elevated levels of aluminum, arsenic, barium, copper, iron, lead, vanadium, and zinc were detected in surface water samples collected from the northern branches of OU3. These samples were collected during storm events and the elevated levels have been attributed to suspended soils and sediment from runoff which affected the sample results.

Arsenic, beryllium, chromium, cobalt, copper, lead, selenium and vanadium were detected in subsurface soil samples above site background concentrations. Most of the elevated metal concentrations were present in samples collected from MW-55 and MW-56, located just north of the Main Compound and west of the PCB excavation trench.

2.11 FISH TISSUE RESIDUE ANALYSES

Fish tissue residue analysis was performed on fillet and whole body samples of fish collected at selected locations throughout WRF. Two of the fish collection zones were located downstream from the Main Compound area in the Main Ditch as presented in Figure 2-22. The results of the fish tissue analyses are presented in Sections 3.0 (Human Health Risk Assessment) and Section 4.0 (Ecological Risk Assessment).



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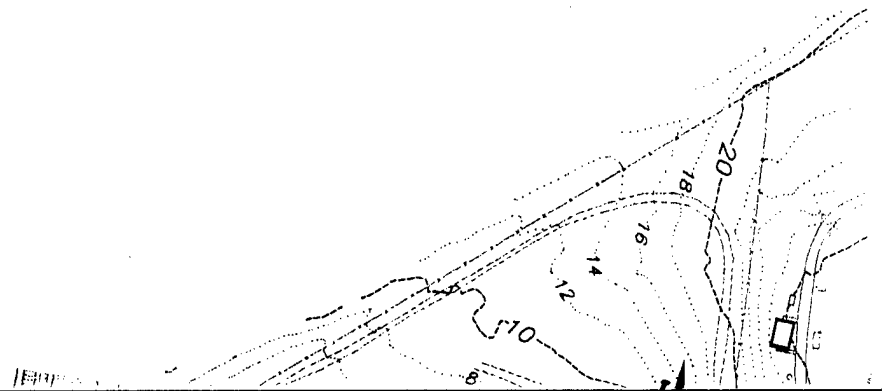
Figure 2-1
WOODBRIDGE RESEARCH FACILITY

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1301 Continental Drive
Suite 101
Abingdon, Maryland 21009
(410) 612-6350

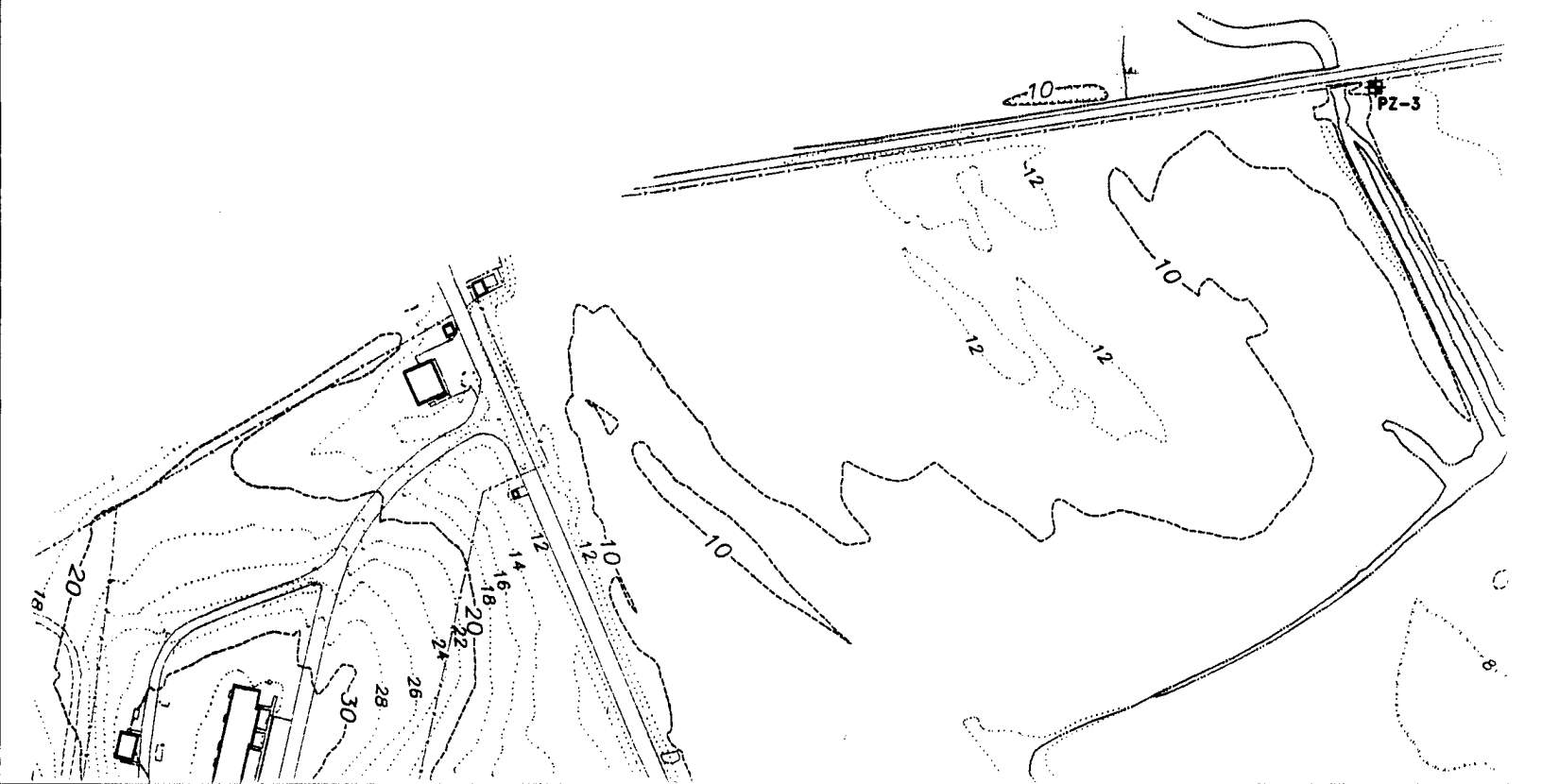
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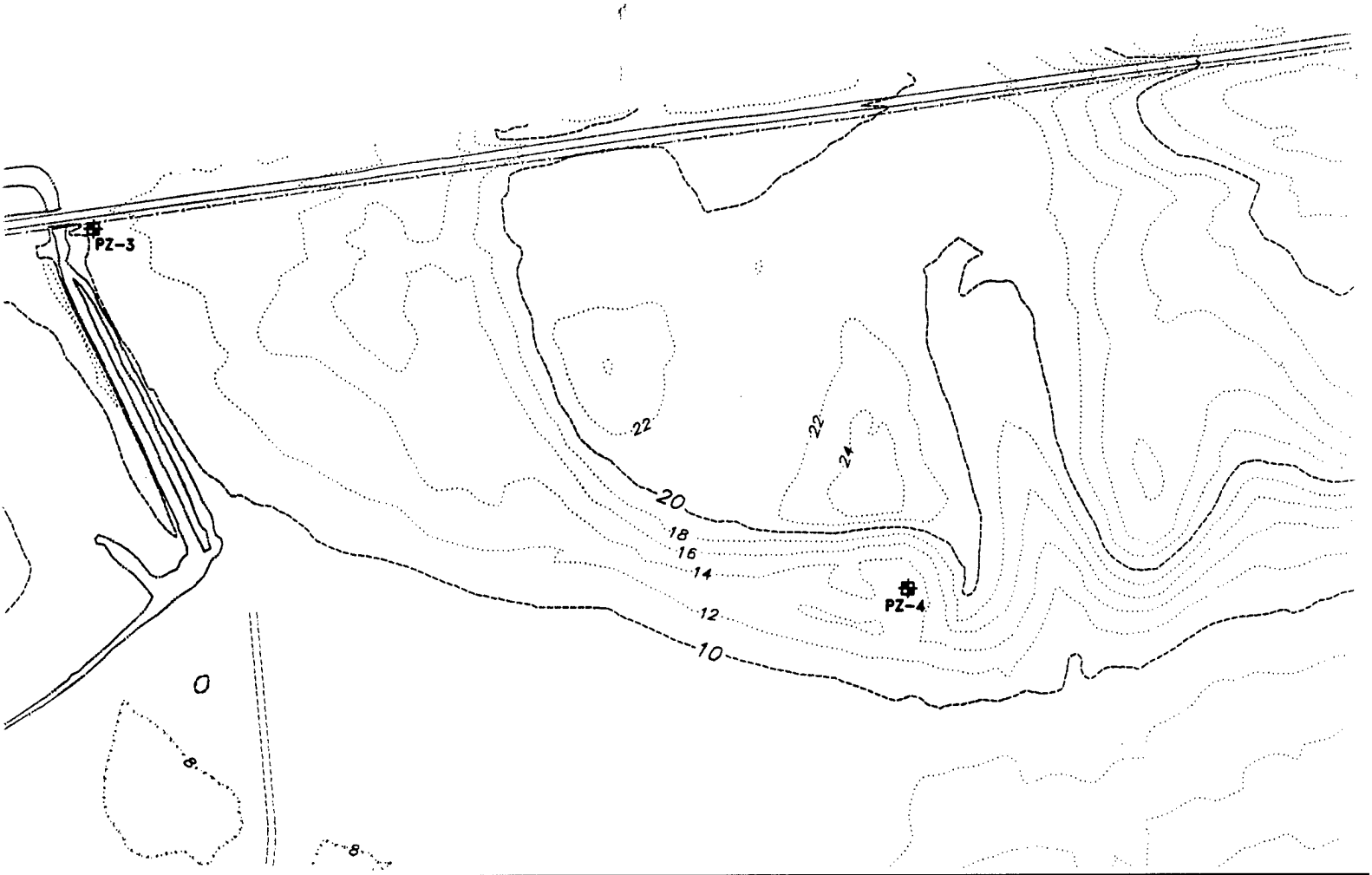
WRF LOCATION MAP

(1)

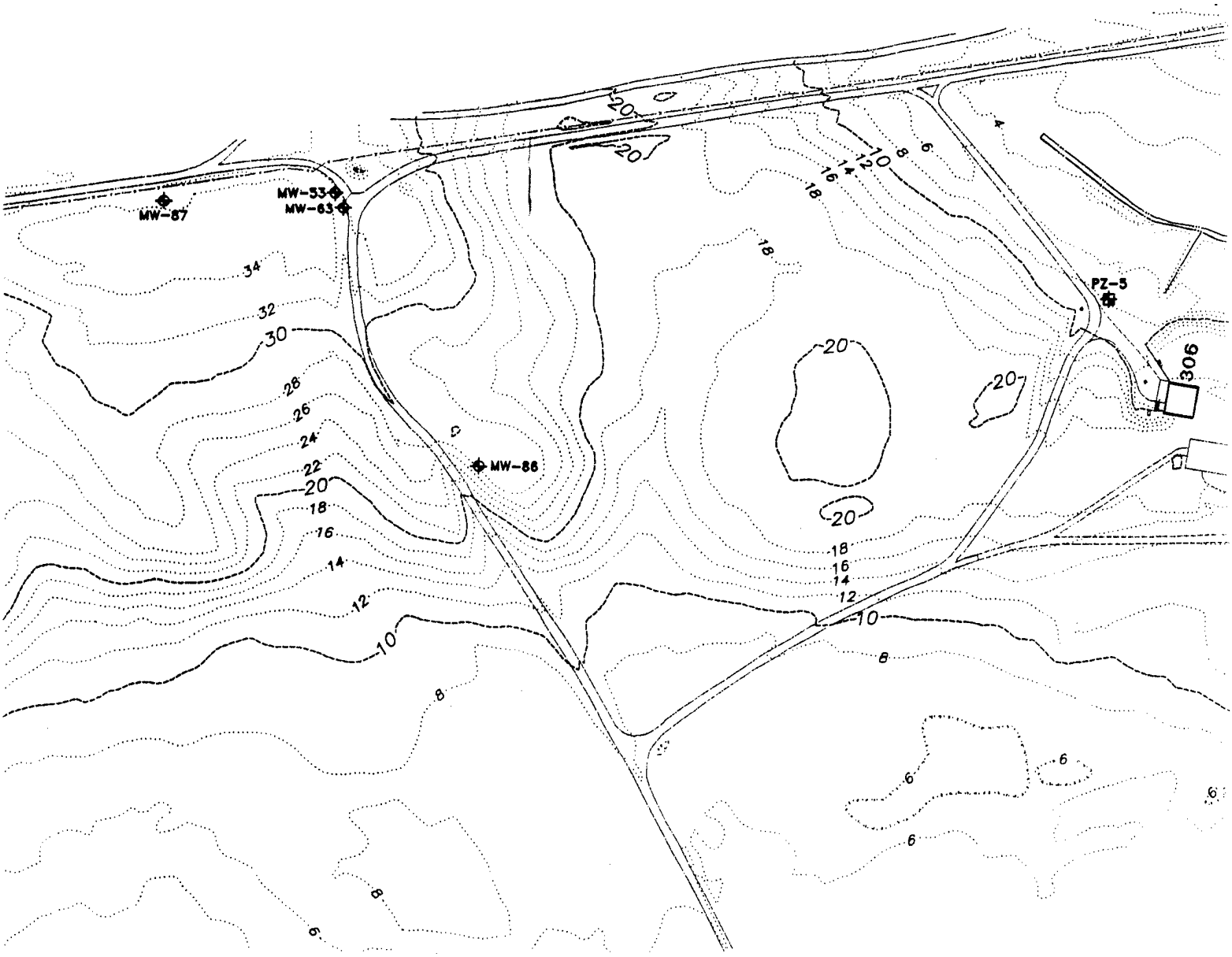


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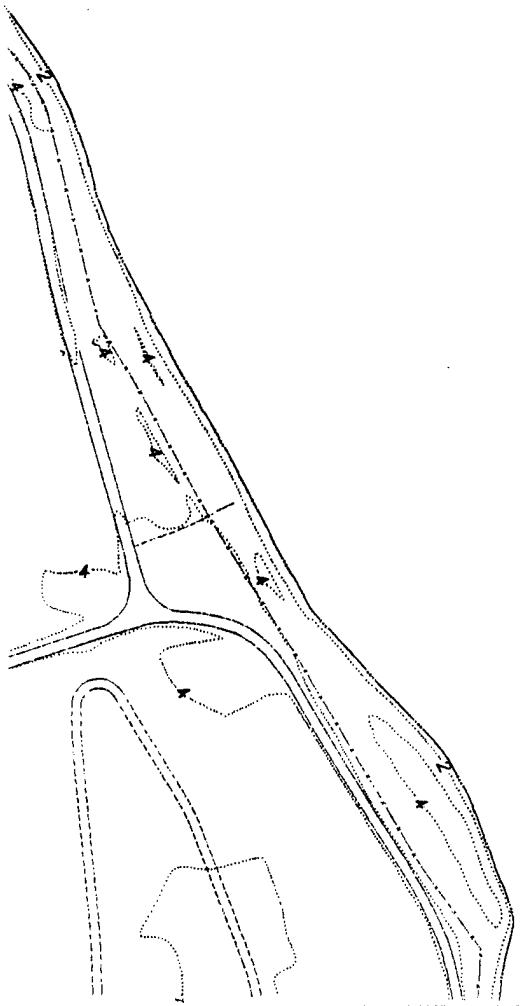

PZ-3
PZ-4
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(4)

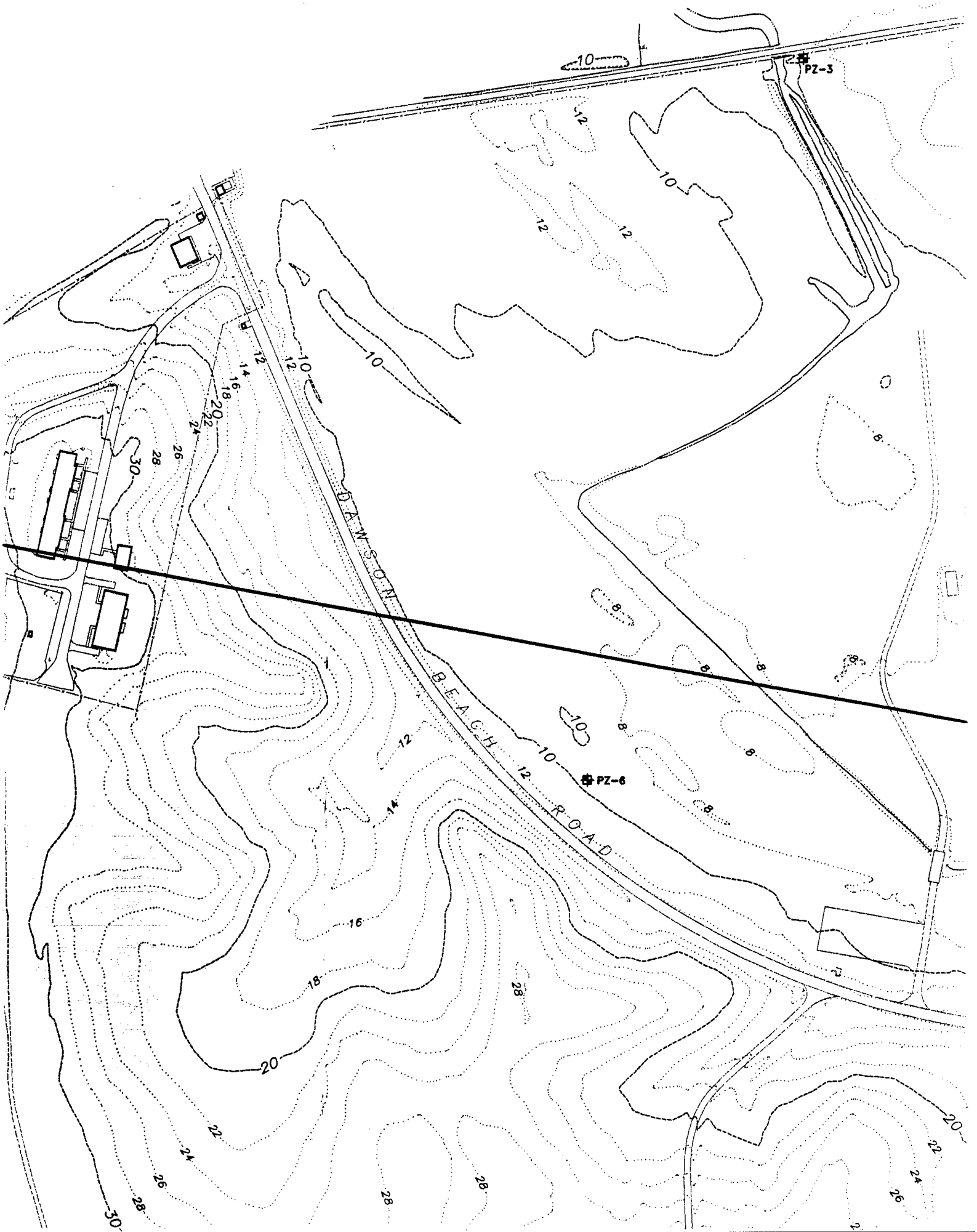

MW-87
MW-53
MW-63
MW-86
PZ-5
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(5)

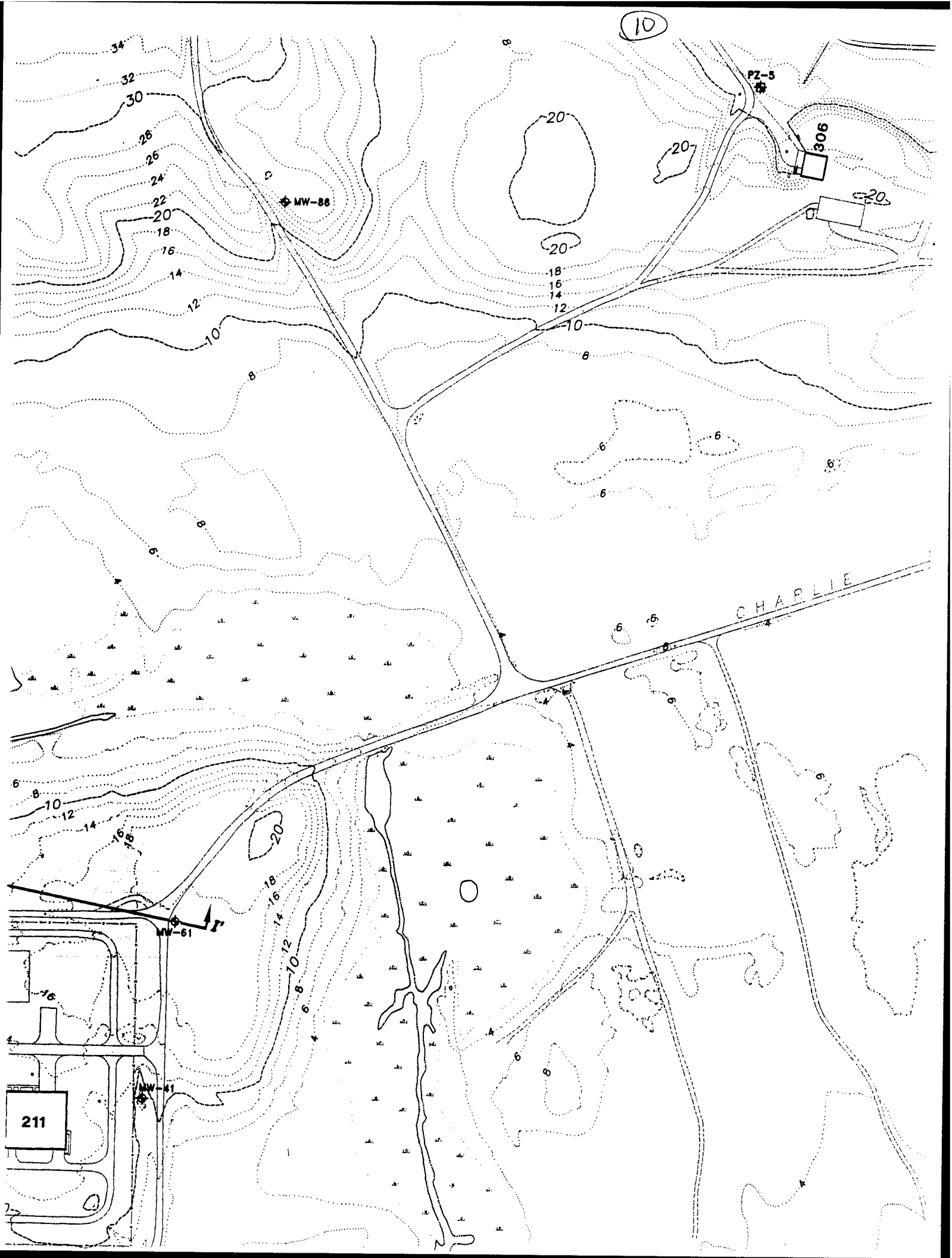




MW-52
Creek
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18
16
14
12
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6
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12
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PZ-3
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DAWSON BEACH ROAD

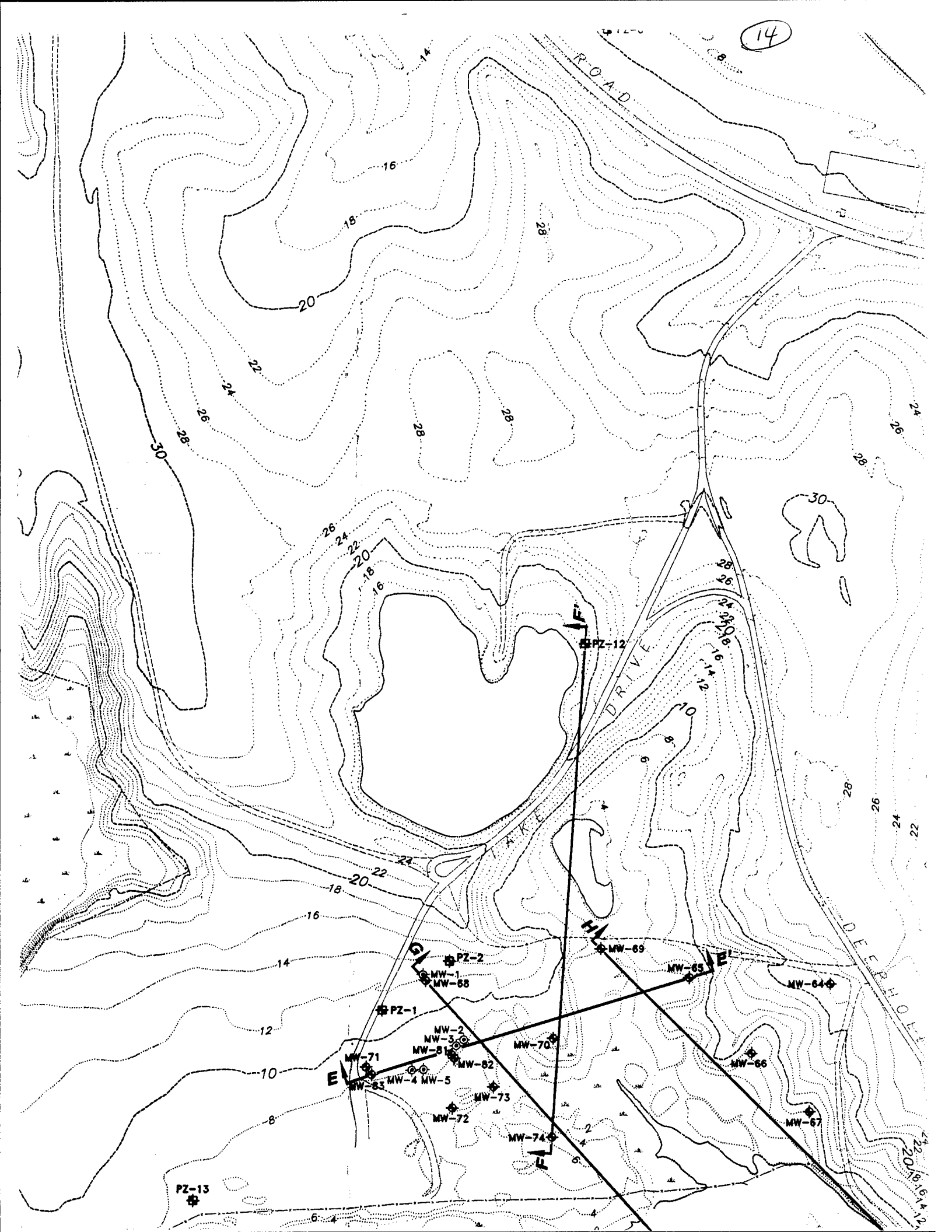

9
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MW-57
MW-62
MW-56
MW-85
MW-58
MW-55
MW-39
MW-84
LOCUST RD
MW-33
MW-38
MW-37
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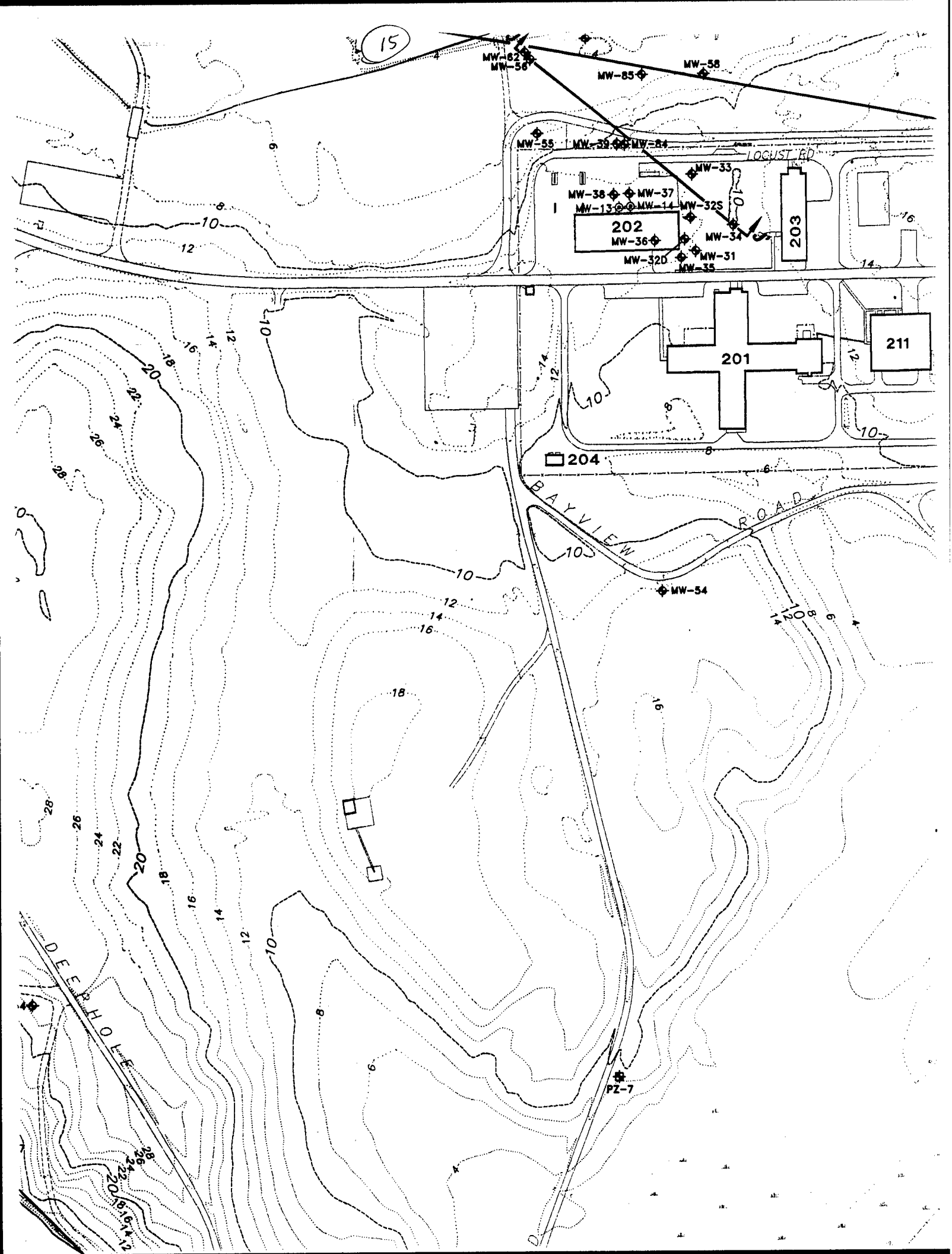

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PZ-5
306
MW-86
MW-61
MW-41
211
CHARLIE

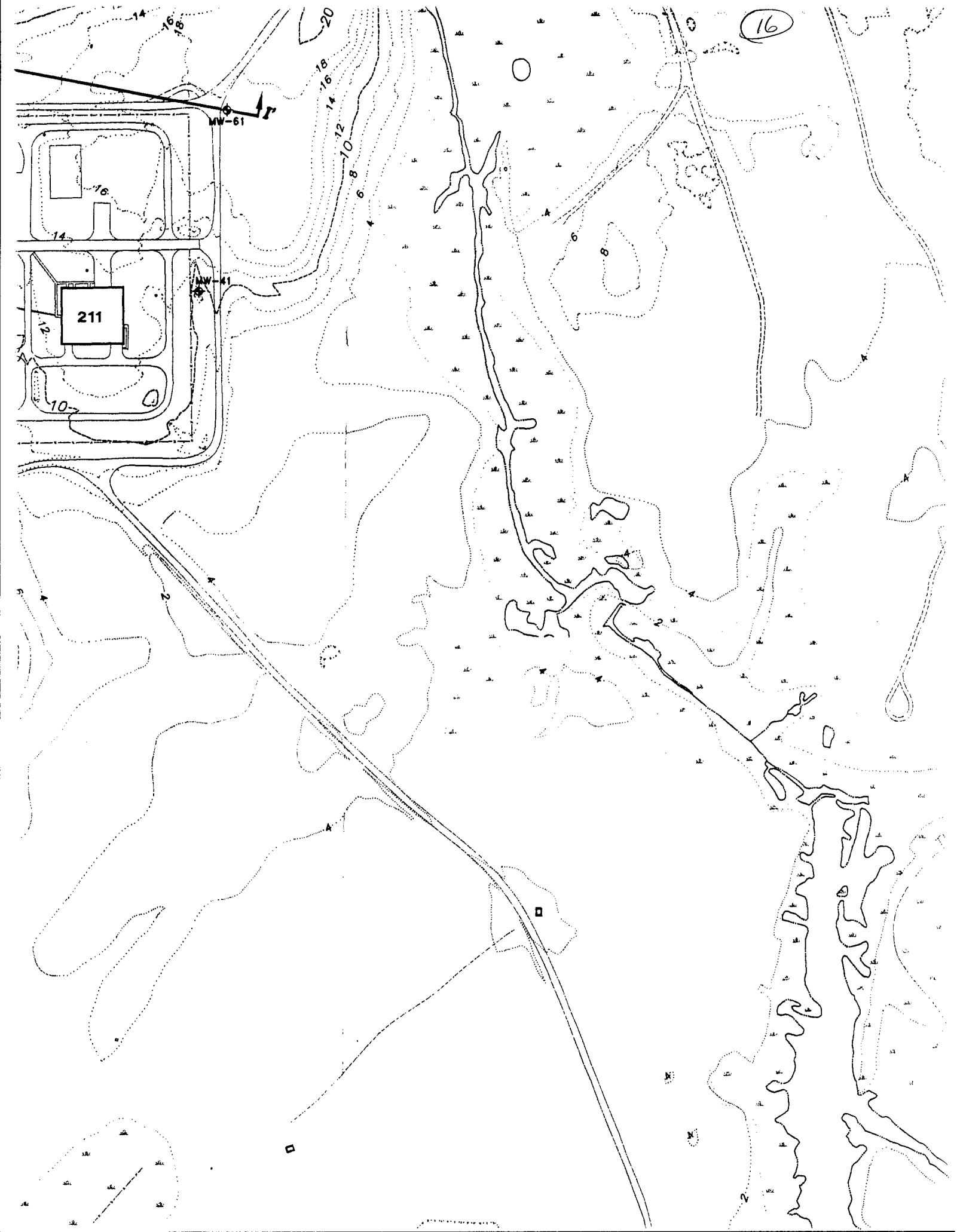

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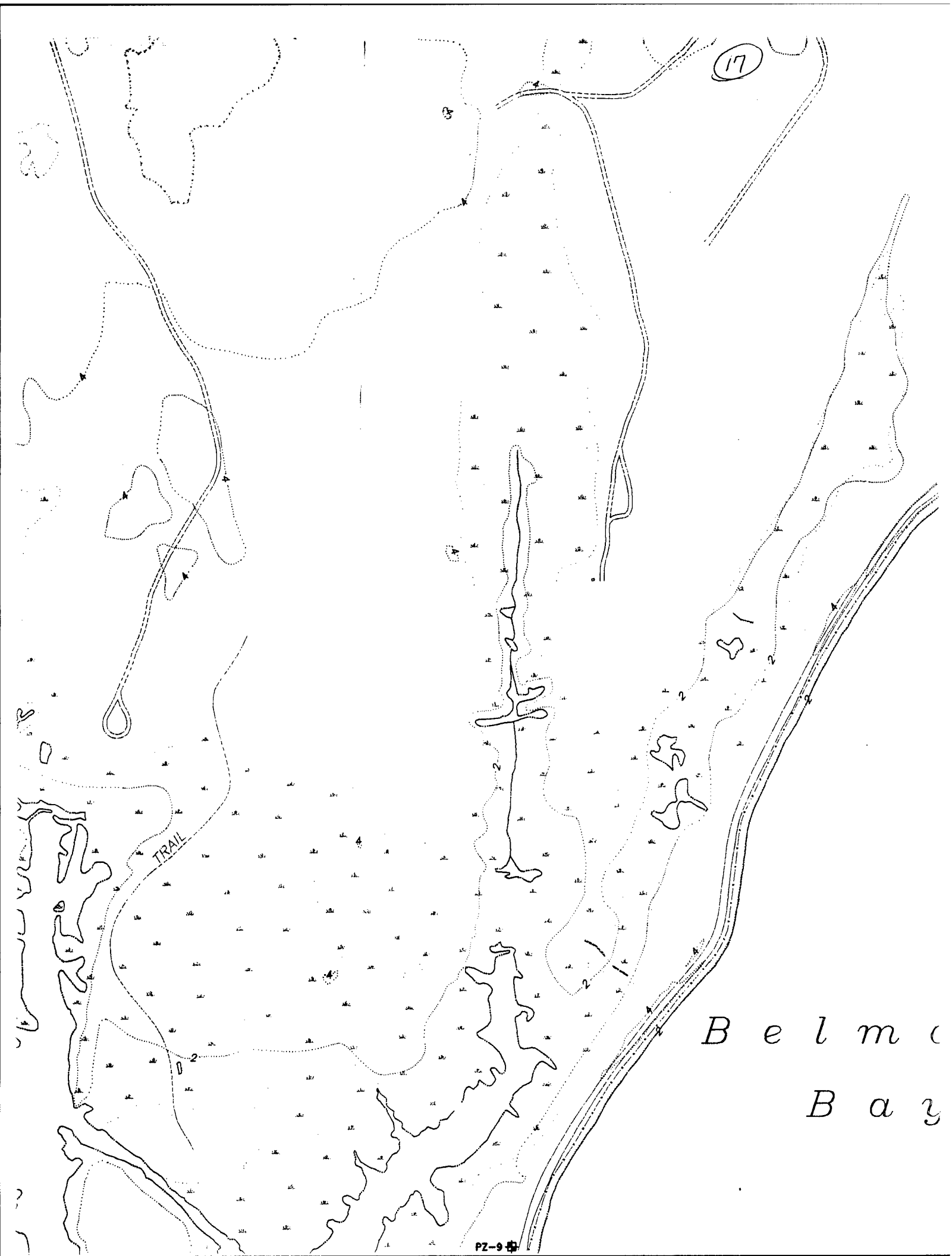
12


VETERANS DRIVE
Marumsco Creek
13


14
ROAD
LAKE DRIVE
DEER HOLL
PZ-12
PZ-2
PZ-1
PZ-13
MW-1
MW-68
MW-2
MW-3
MW-81
MW-82
MW-71
MW-83
MW-4
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LOCUST RD
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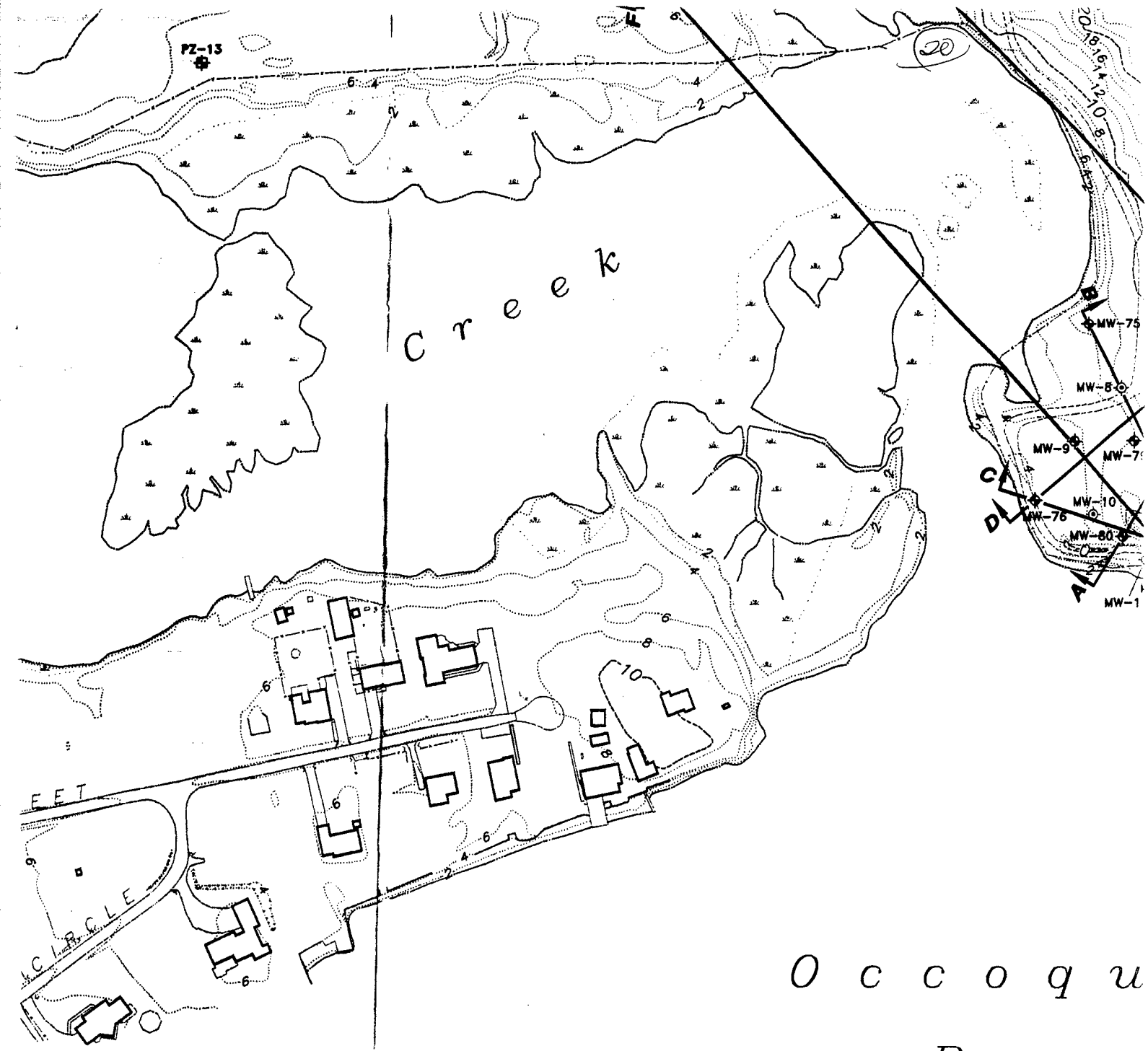

17
TRAIL
Belmo
Bay
PZ-9



LEGEND:

- MONITC
- PIEZOM
- MONITC GEOLO
- 20
- 18


Tarumco
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BAY STREET
BAY CIRCLE
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16
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PZ-13
Creek
MW-75
MW-8
MW-9
MW-7
MW-10
MW-76
MW-80
MW-1
A
C
D
EET
CIRCLE
Occoqu
Bay


21
FOX ROAD
POINT ROAD
MW-59
MW-75
MW-60
MW-5
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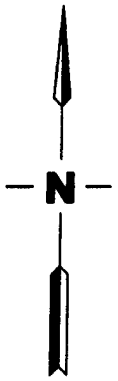
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SWAMP (24)



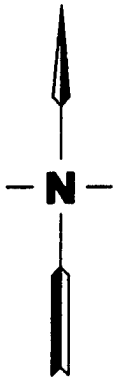
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SCALE FEE

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SWAMP

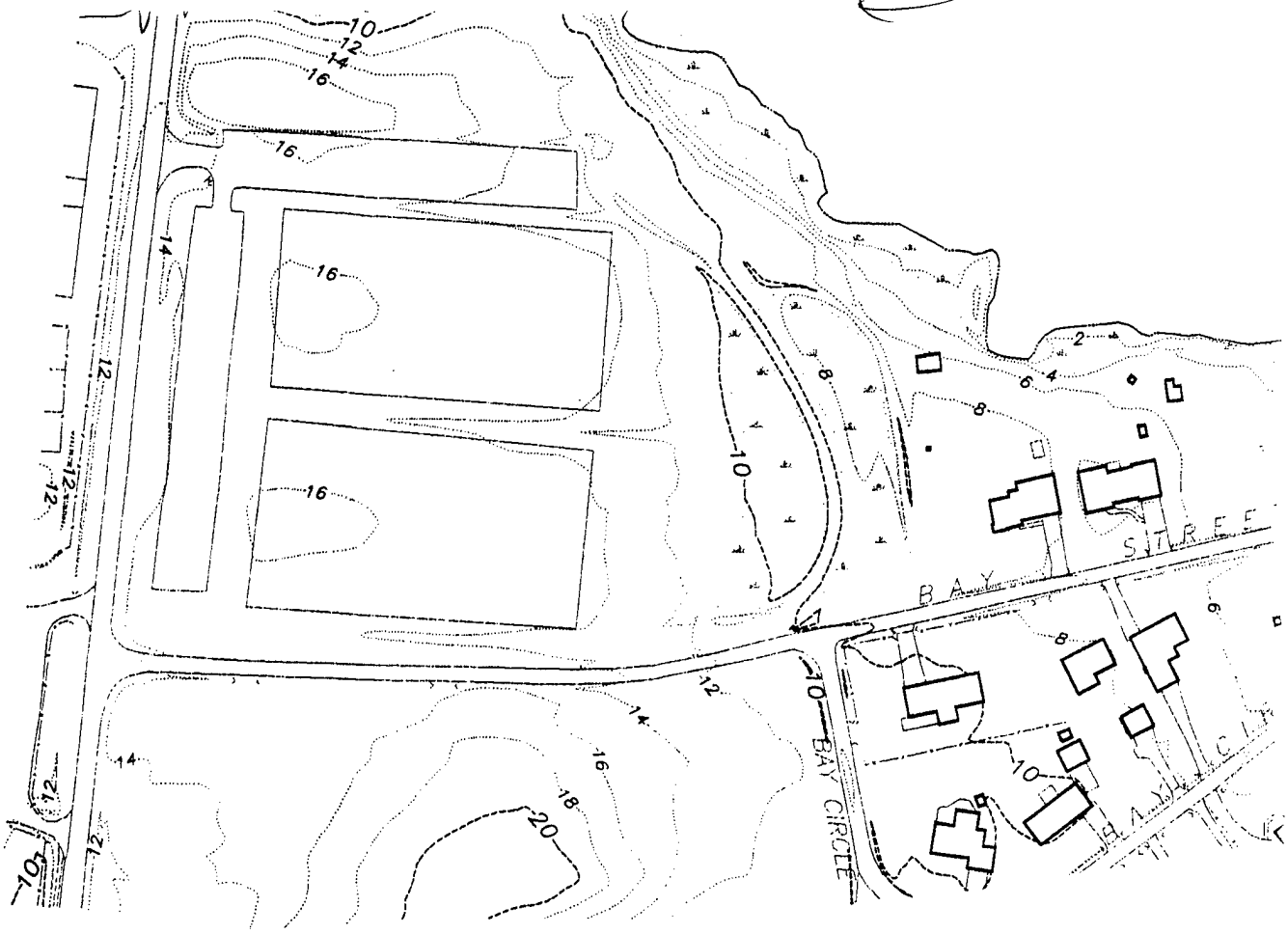
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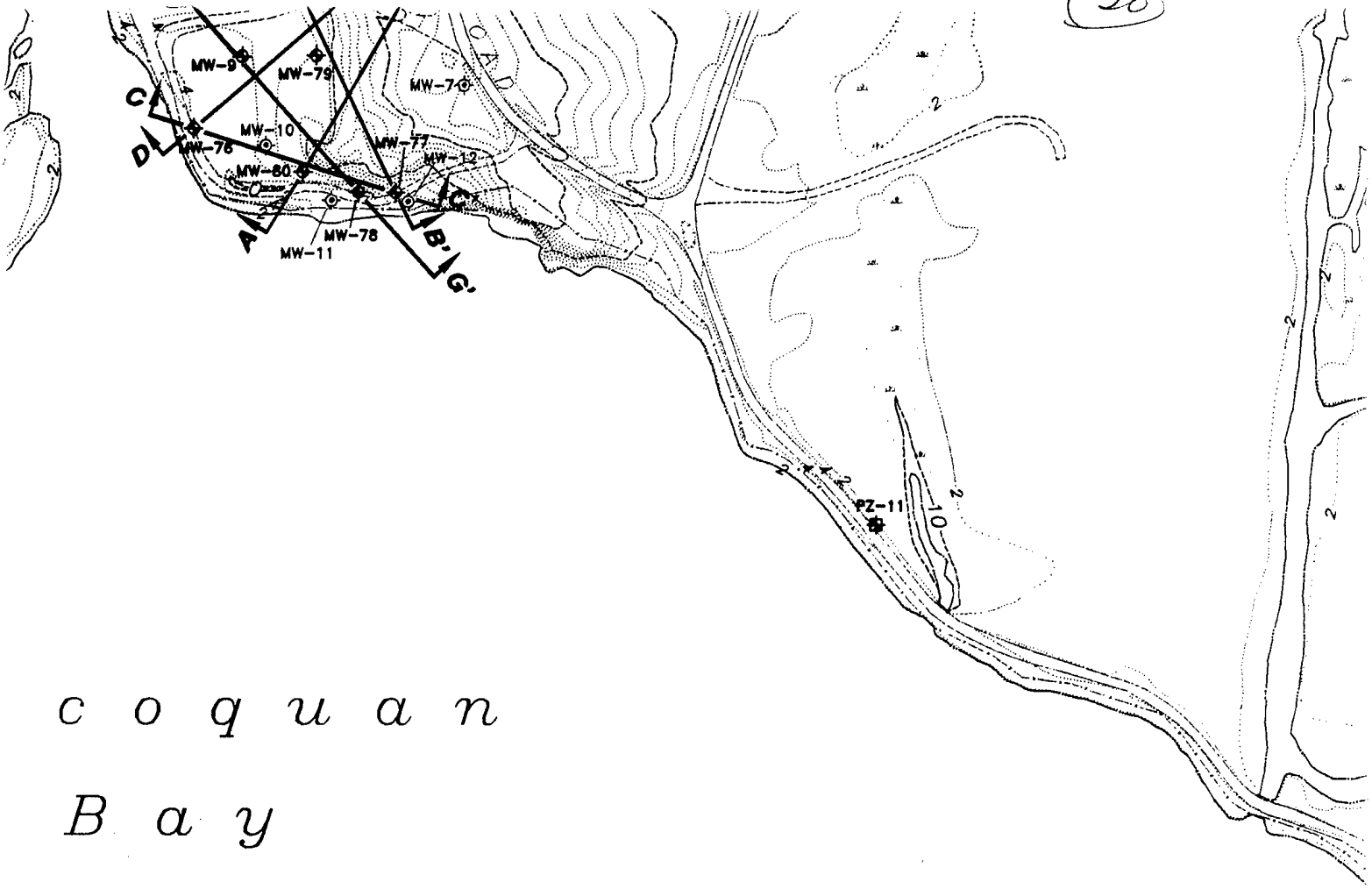
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BAY
STREET
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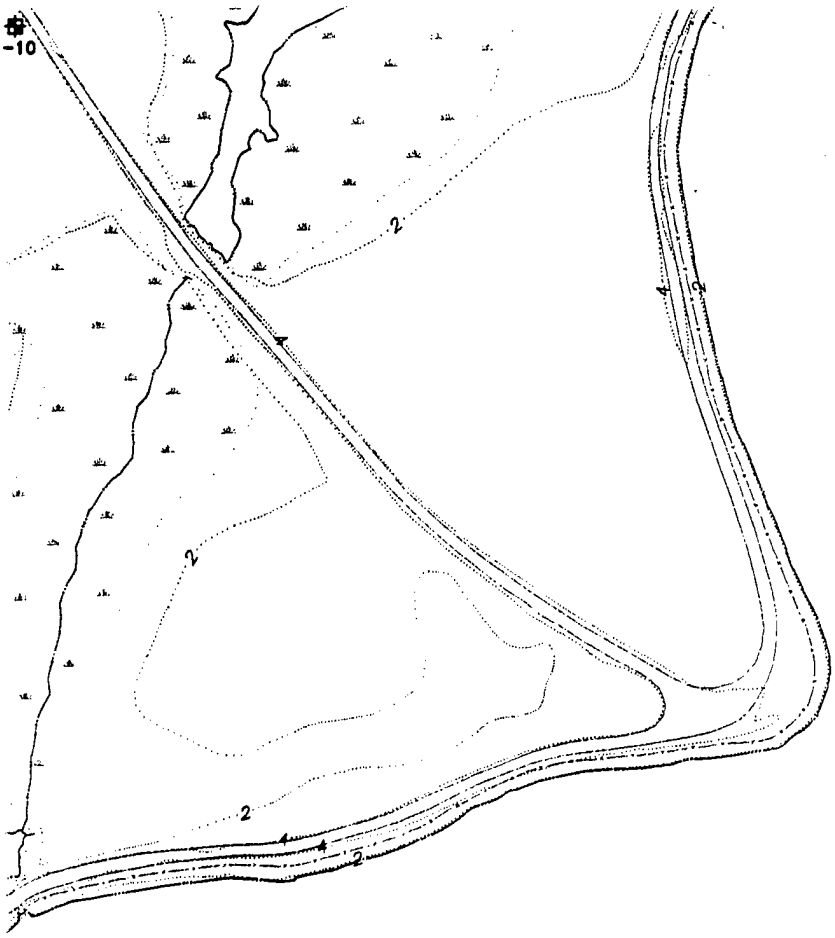
Ba


MW-9
MW-79
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MW-76
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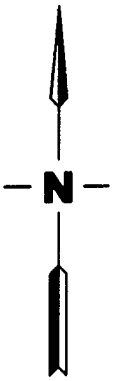
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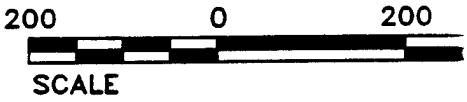
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2

(31)





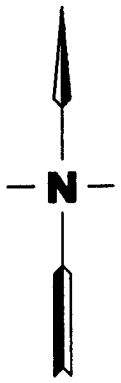
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2113 Emmorton Park Drive
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Edgewood, Maryland 21040
(410) 612-6350

PREPARED CST	TASK NO: 66220
CHECKED PT	ICF DWG NO:
DATE 08-18-97	STE-TOPO

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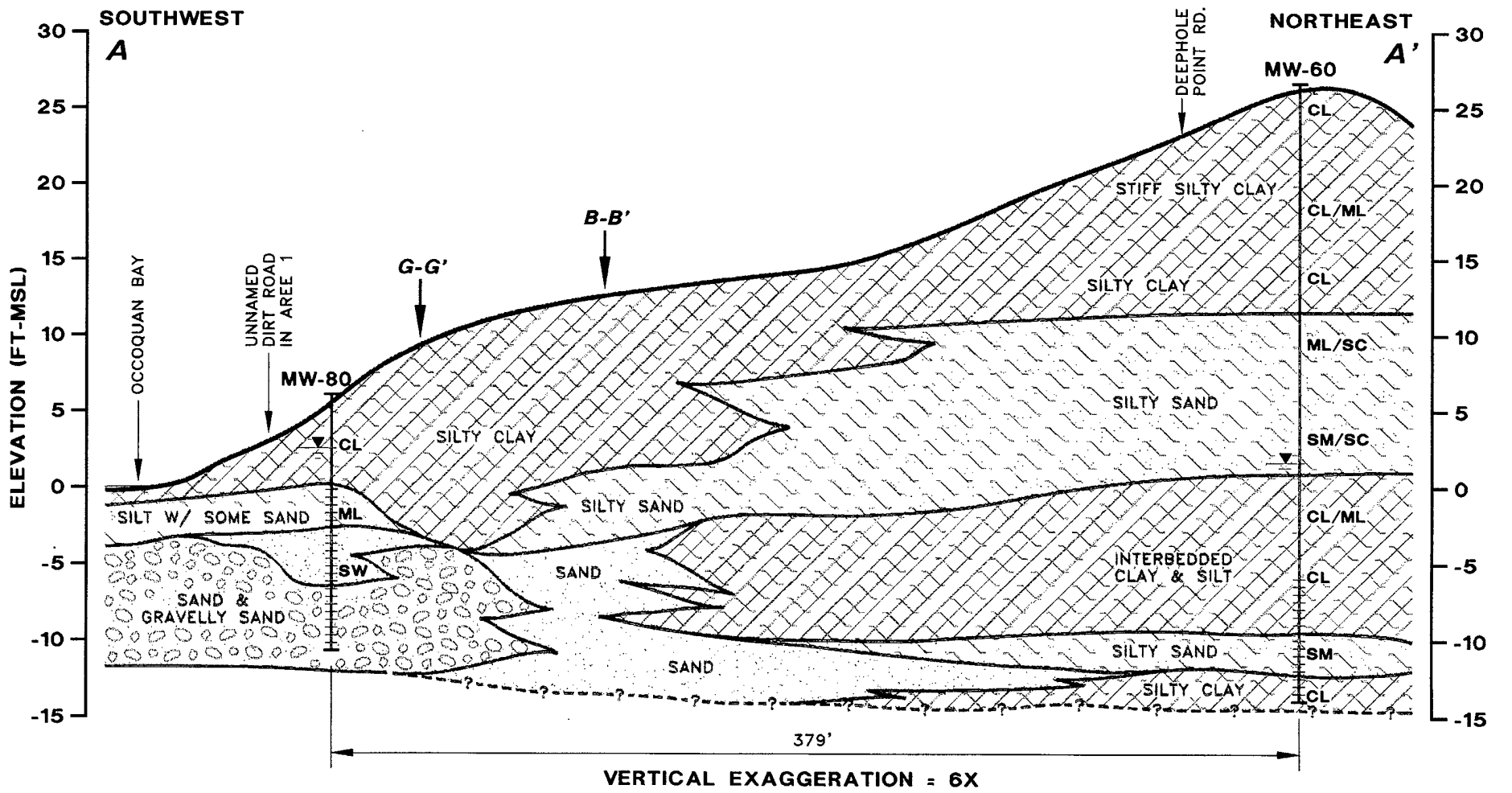


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CONTRACT NO. DACA31-94-D-0064	FIGURE 2-2 WOODBRIDGE RESEARCH FACILITY
ICF KAISER 2113 Emmorton Park Drive Suite 100 Edgewood, Maryland 21040 (410) 612-6350	**SITE-WIDE TOPOGRAPHIC CONTOUR MAP**
PREPARED CST	TASK NO: 66220
CHECKED PT	ICF DWG NO: STE-TOPO
DATE 08-18-97	



FIGURE 2-3 - REGIONAL GEOLOGIC MAP
(Excerpt from Mixon, et al, 1989)
Scale = 1:250,000

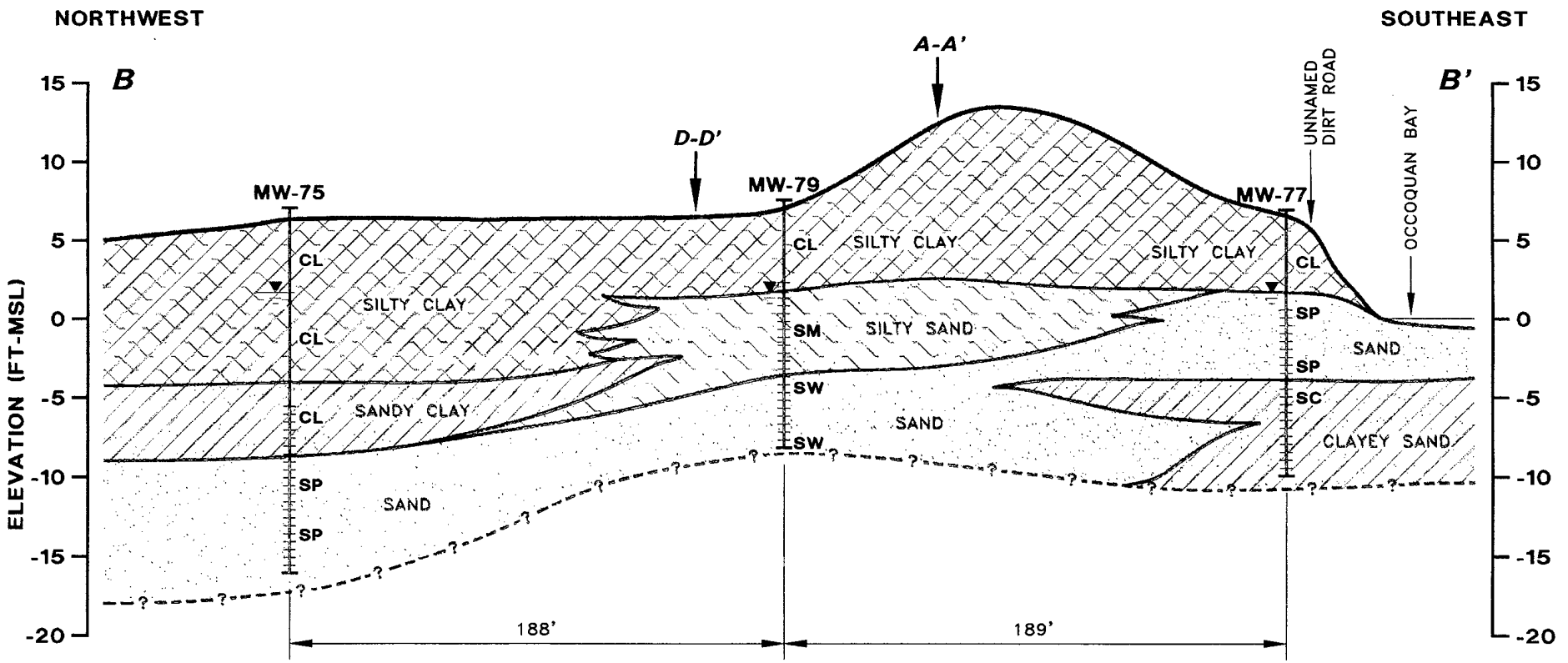


LEGEND:

- GROUNDWATER ELEVATION MEASURED JAN. 5, 1996
- GRAVEL
- SILT
- SAND
- CLAY

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CONTRACT NO. DACA31-94-D-0064	FIGURE 2-4 WOODBRIDGE RESEARCH FACILITY
ICF KAISER 2113 Emmorton Park Drive Suite 100 Edgewood, Maryland 21040 (410) 612-6350	GEOLOGIC CROSS SECTION A-A'
PREPARED CST / TASK NO: 66220	
CHECKED PT / ICF DWG NO: WRF-XSA	
DATE 08-20-97	



VERTICAL EXAGGERATION = 6X

LEGEND:

- ▼ GROUNDWATER ELEVATION MEASURED JAN. 5, 1996
- GRAVEL
- SILT
- SAND
- CLAY

US ARMY ENVIRONMENTAL CENTER

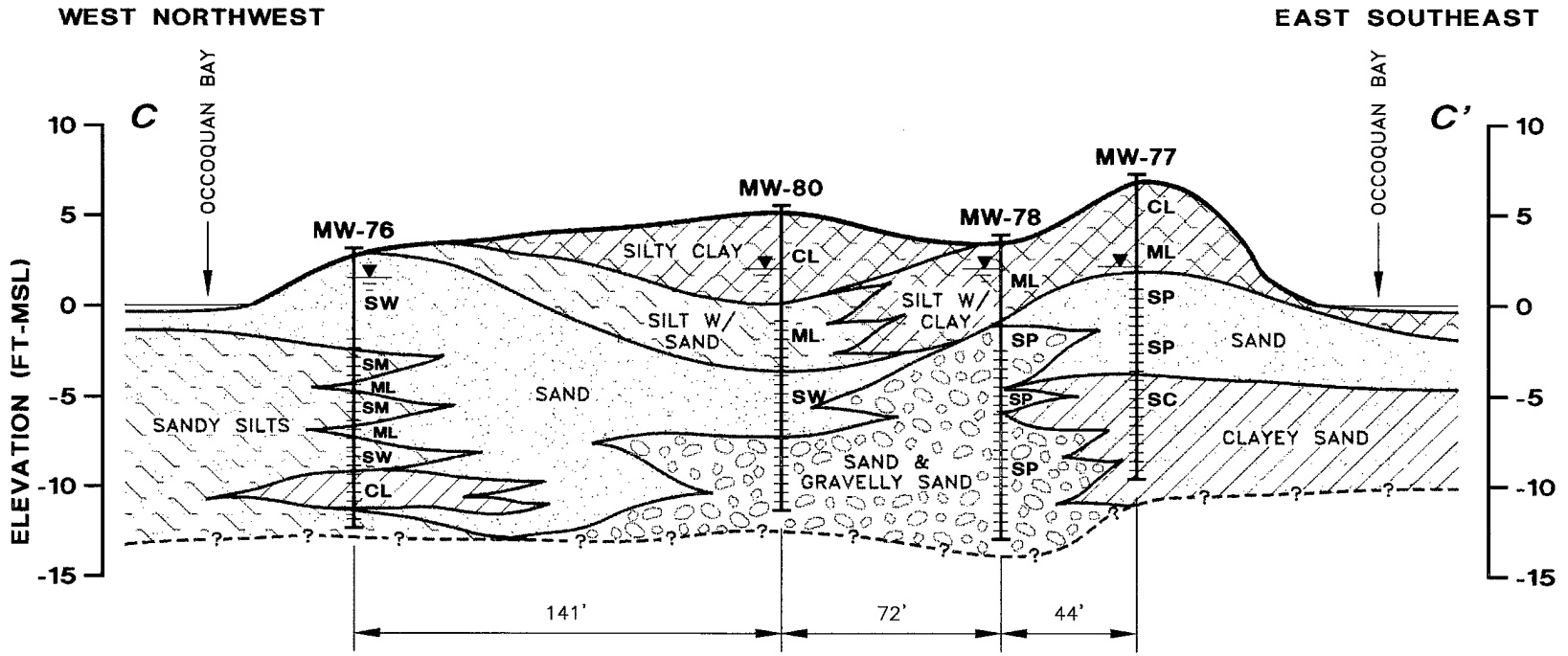
CONTRACT NO. DACA31-94-D-0064

FIGURE 2-5
WOODBRIDGE RESEARCH FACILITY

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2113 Emmorton Park Drive
Suite 100
Edgewood, Maryland 21040
(410) 612-6350

PREPARED CST	TASK NO: 66220
CHECKED PT	ICF DWG NO: WRF-XSB
DATE 08-15-97	

GEOLOGIC CROSS SECTION B-B'



VERTICAL EXAGGERATION = 6X

LEGEND:

GROUNDWATER ELEVATION MEASURED JAN. 5, 1996

GRAVEL

SILT

SAND

CLAY

US ARMY ENVIRONMENTAL CENTER

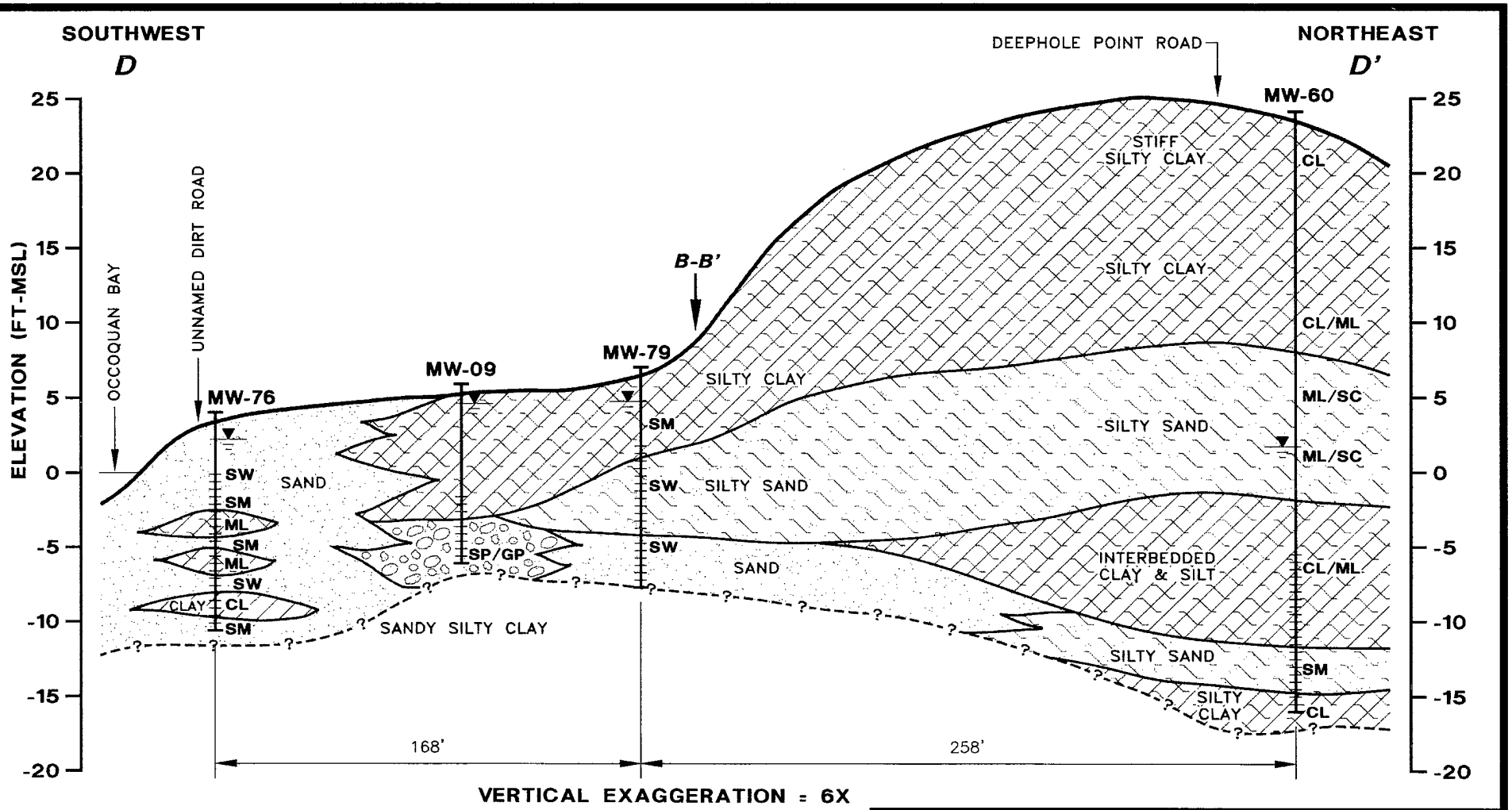
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FIGURE 2-6
WOODBRIDGE RESEARCH FACILITY

ICF KAISER
2113 Emmorton Park Drive
Suite 100
Edgewood, Maryland 21040
(410) 612-6350

GEOLOGIC CROSS SECTION C-C'

PREPARED CST	TASK NO: 66220
CHECKED PT	ICF DWG NO: WRF-XSC
DATE 08-15-97	

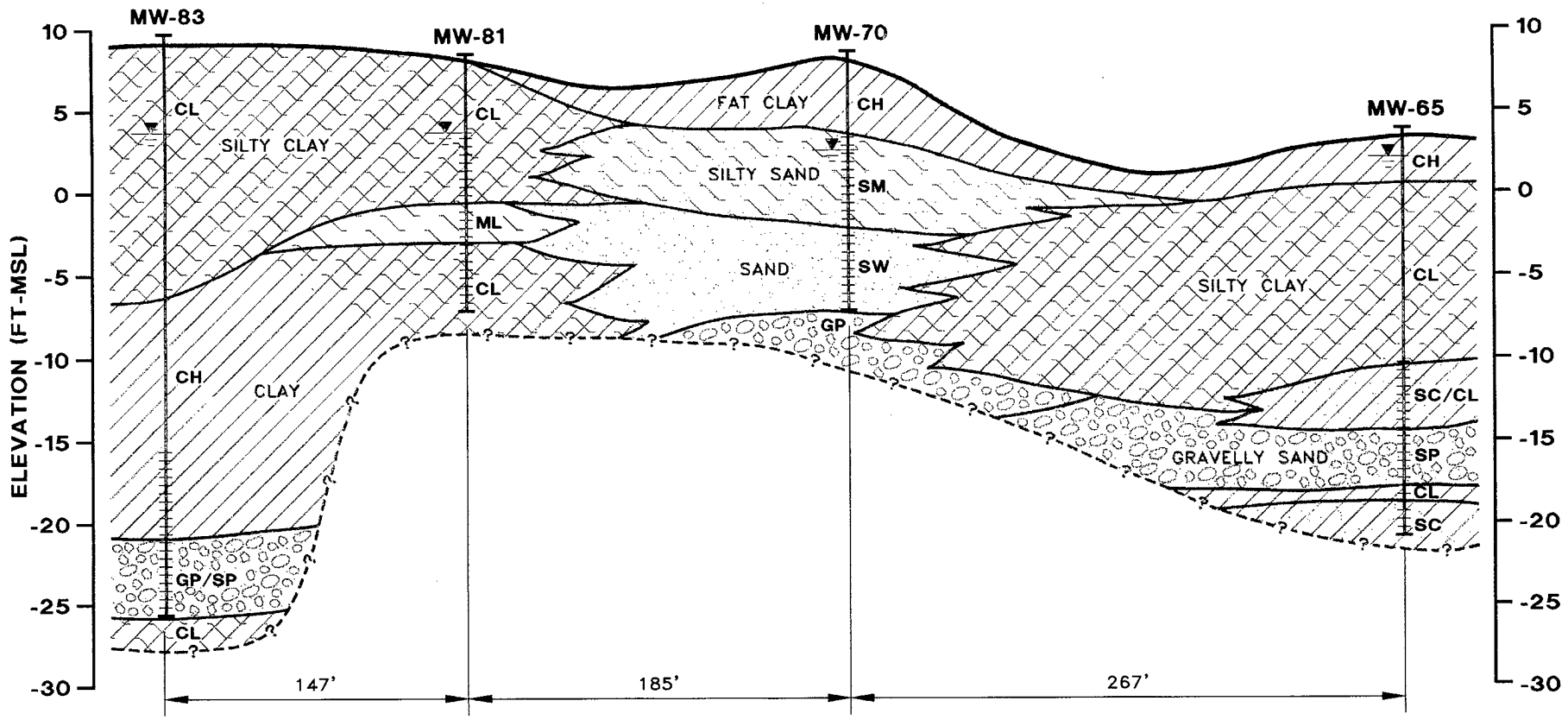


LEGEND:

- GROUNDWATER ELEVATION MEASURED JAN. 5, 1996
- GRAVEL
- SILT
- SAND
- CLAY

US ARMY ENVIRONMENTAL CENTER

CONTRACT NO. DACA31-94-D-0064	FIGURE 2-7 WOODBRIDGE RESEARCH FACILITY
ICF KAISER 2113 Emmorton Park Drive Suite 100 Edgewood, Maryland 21040 (410) 612-6350	GEOLOGIC CROSS SECTION D-D'
PREPARED CST	TASK NO: 66220
CHECKED PT	ICF DWG NO: WRF-XSL
DATE 08-20-97	



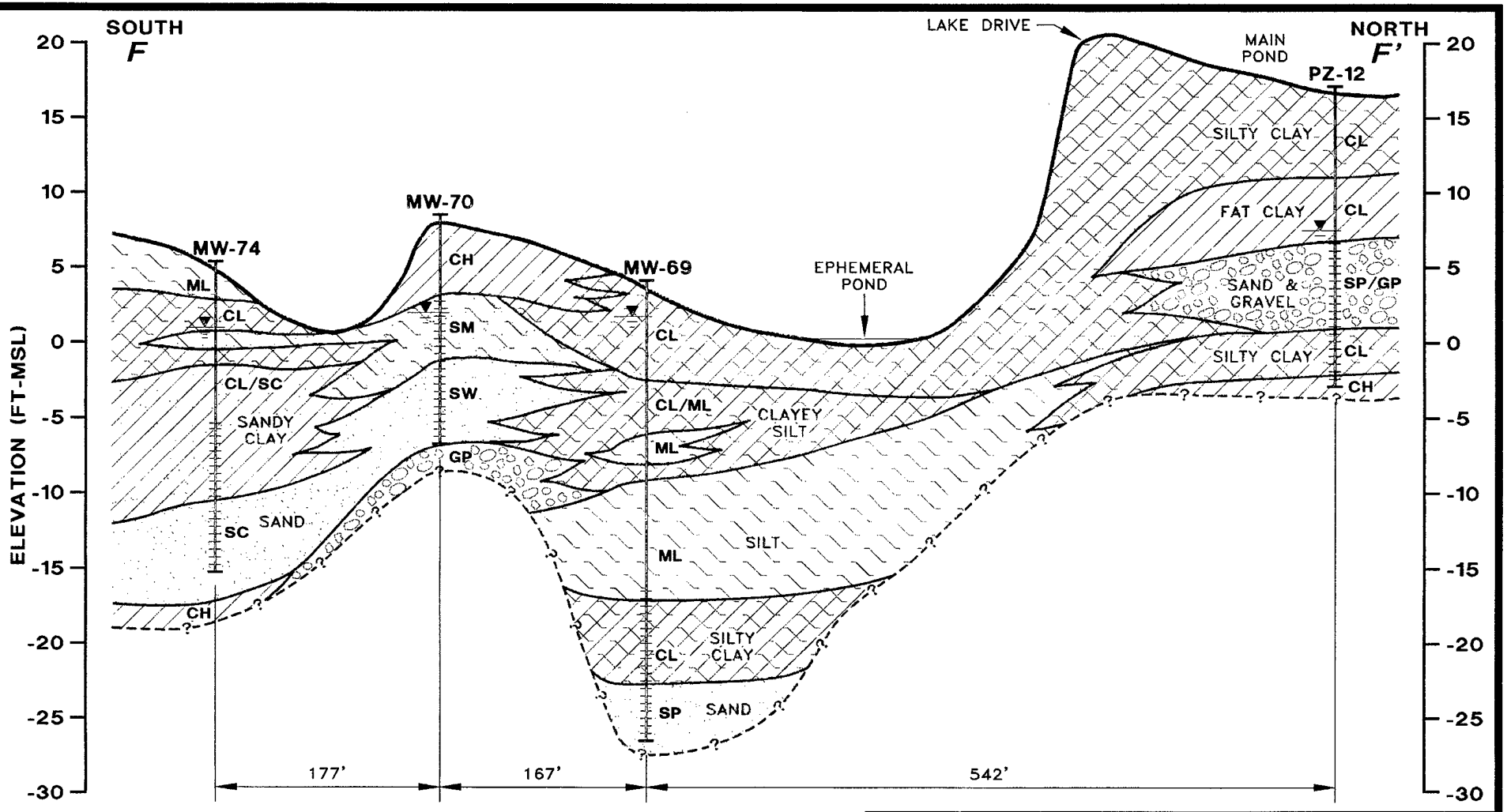
LEGEND:

GROUNDWATER ELEVATION MEASURED JAN. 5, 1996

GRAVEL | SILT | SAND | CLAY

US ARMY ENVIRONMENTAL CENTER

CONTRACT NO. DACA31-94-D-0064	FIGURE 2-8
ICF KAISER 2113 Emmorton Park Drive Suite 100 Edgewood, Maryland 21040 (410) 612-6350	WOODBRIDGE RESEARCH FACILITY
PREPARED CST	TASK NO: 66220
CHECKED PT	ICF DWG NO: WRF-XSE
DATE 08-15-97	GEOLOGIC CROSS SECTION E-E'



VERTICAL EXAGGERATION = 12X

LEGEND:

GROUNDWATER ELEVATION MEASURED JAN. 5, 1996

GRAVEL

SILT

SAND

CLAY

US ARMY ENVIRONMENTAL CENTER

CONTRACT NO. DACA31-94-D-0064

FIGURE 2-9

WOODBRIDGE RESEARCH FACILITY

ICF KAISER
2113 Emmorton Park Drive
Suite 100
Edgewood, Maryland 21040
(410) 612-6350

PREPARED CST

TASK NO: 66220

CHECKED PT

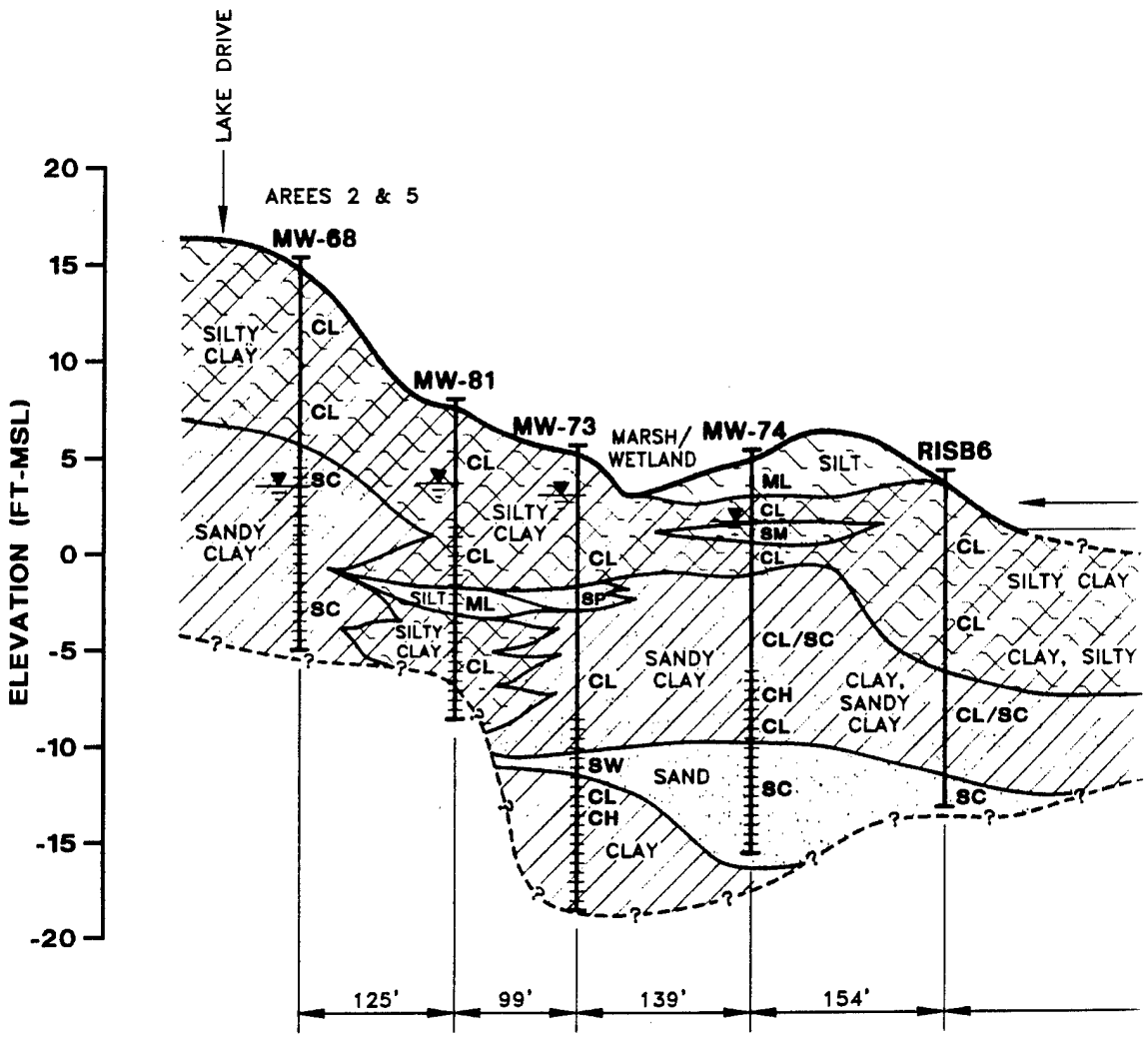
ICF DWG NO: WRF-XSF

DATE 08-25-97

GEOLOGIC CROSS SECTION F-F'

NORTHWEST

G



VERTICAL

LEGEND:

▼ GROUNDWATER ELEVATION MEASURED JAN. 5, 1996

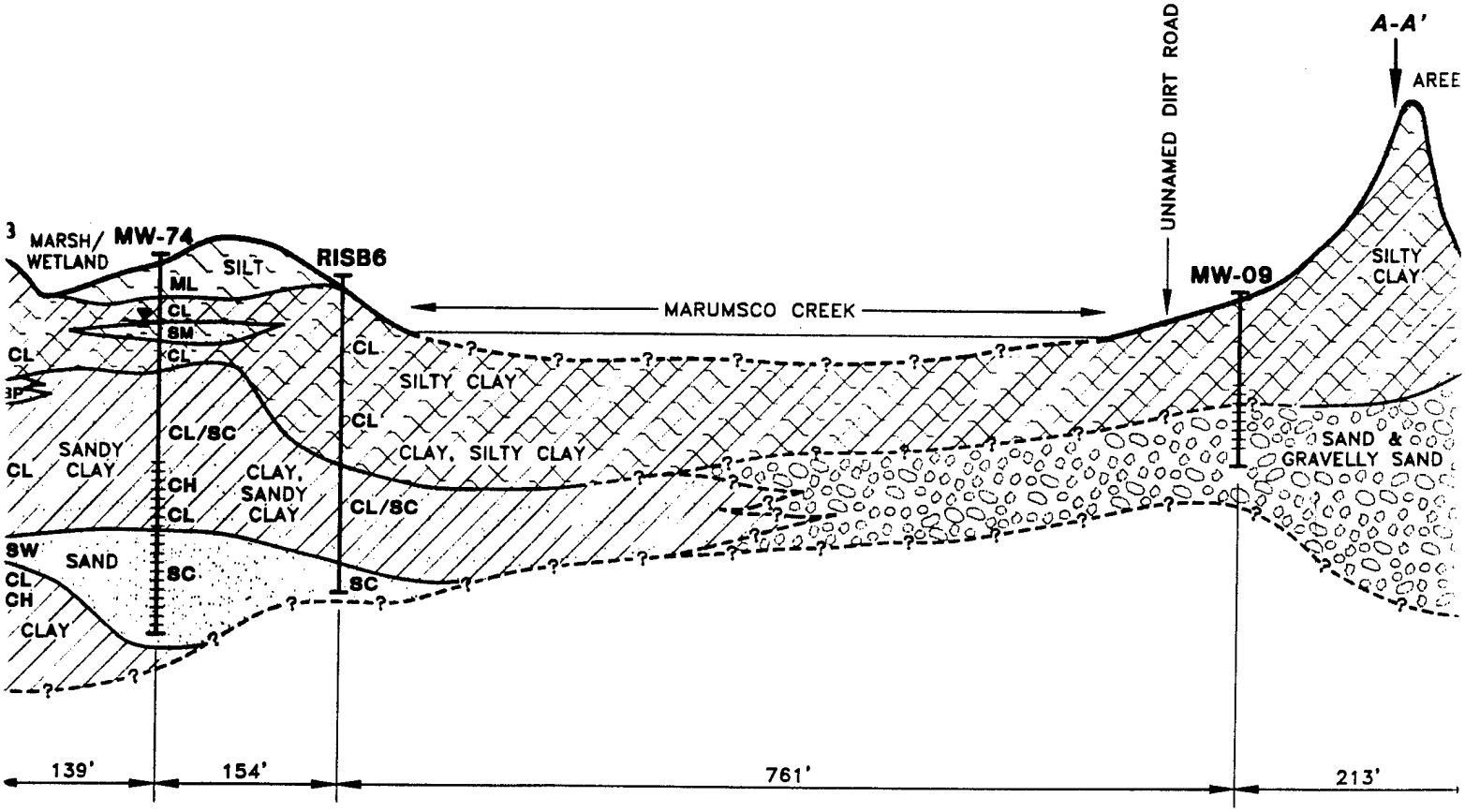
GRAVEL

SILT

SAND

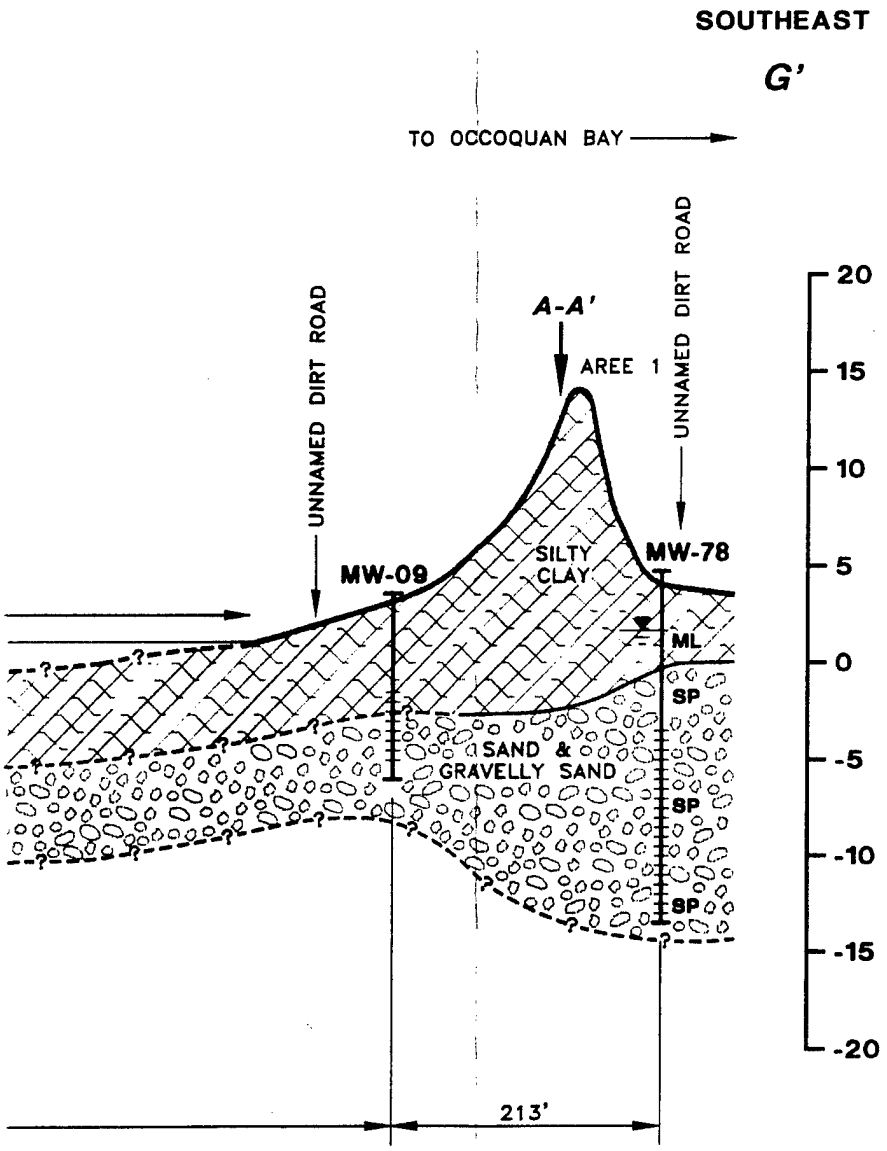
CLAY

TO OCCOQUAN BAY



VERTICAL EXAGGERATION = 15X

ENVIRC	
CONTRACT NO. DACA31	
◆ ICF KAISER	211 Suit Edg (41
PREPARED CST	TASI
CHECKED PT	ICF
DATE 08-20-97	

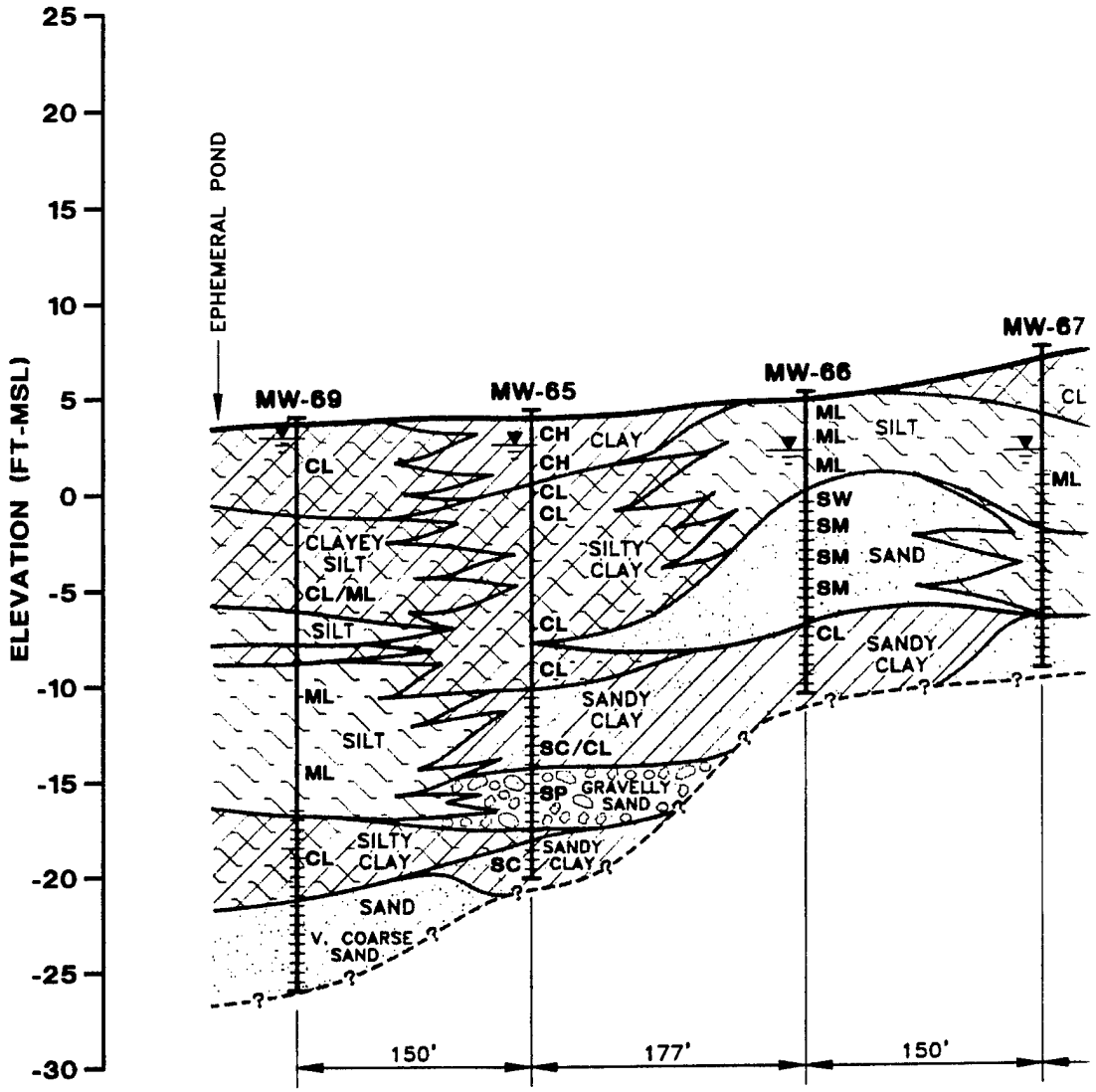


US ARMY ENVIRONMENTAL CENTER

CONTRACT NO. DACA31-94-D-0064	FIGURE 2-10
ICF KAISER 2113 Emmorton Park Drive Suite 100 Edgewood, Maryland 21040 (410) 612-6350	WOODBRIDGE RESEARCH FACILITY
PREPARED CST / TASK NO: 66220	GEOLOGIC CROSS SECTION G-G'
CHECKED PT / ICF DWG NO:	
DATE 08-20-97 / WRF-XSM	

NORTHWEST

H



VERT

LEGEND:

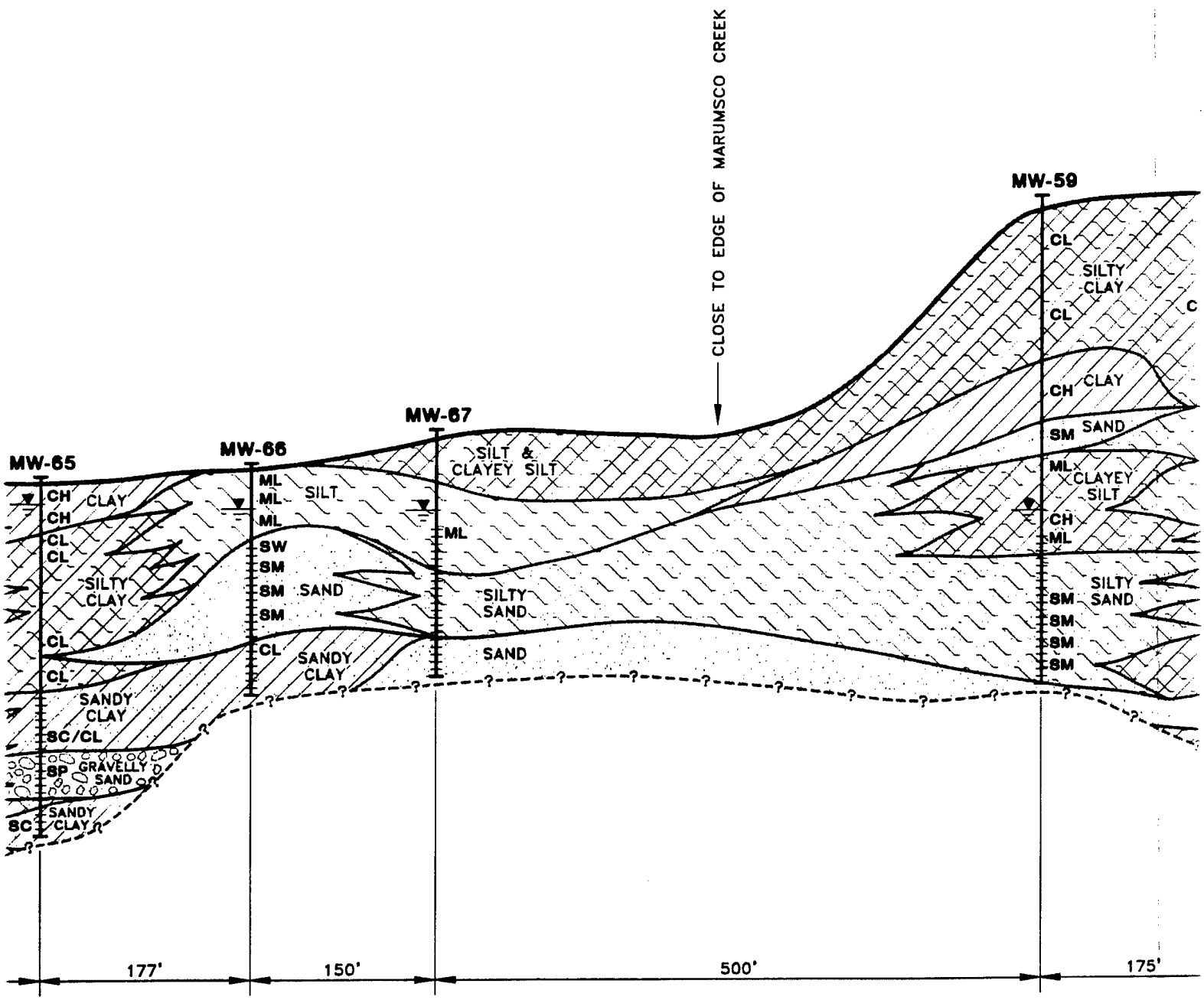
GROUNDWATER ELEVATION MEASURED JAN. 5, 1996

GRAVEL

SILT

SAND

CLAY



VERTICAL EXAGGERATION = 12X

E

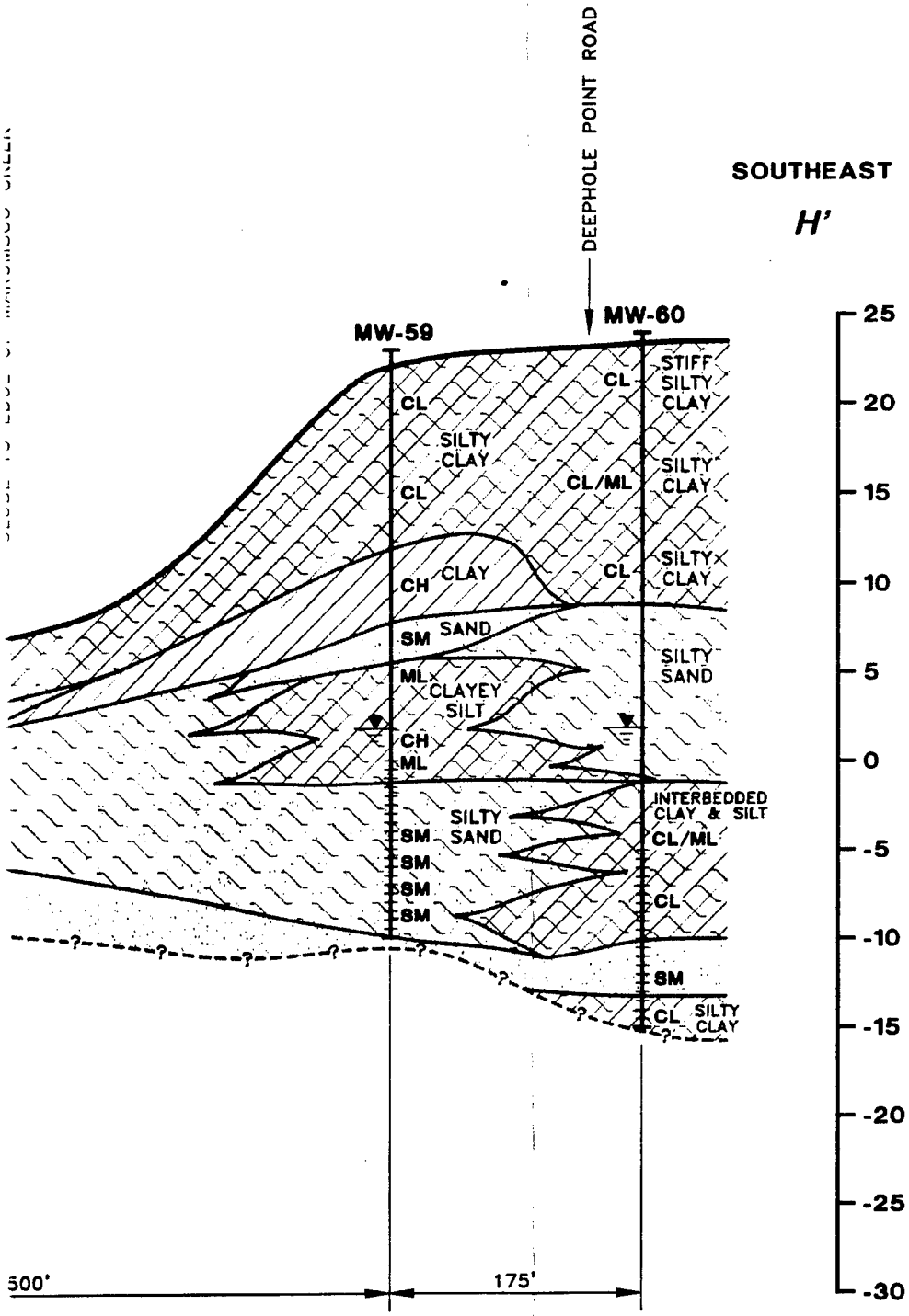
CONTRACT NO

◆ ICF KAI

PREPARED CST

CHECKED PT

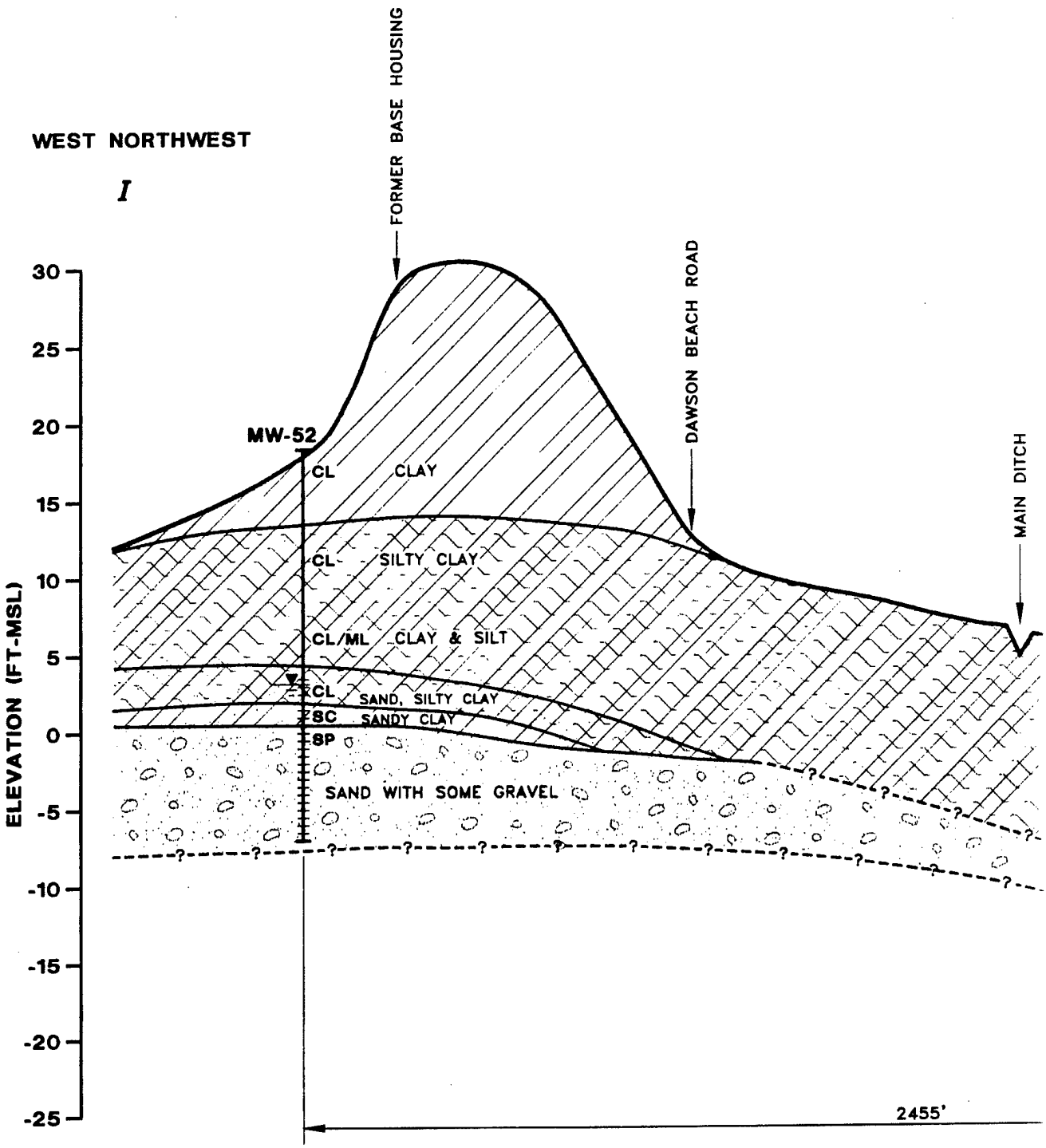
DATE 08-25-9



= 12X

US ARMY ENVIRONMENTAL CENTER

CONTRACT NO. DACA31-94-D-0064	FIGURE 2-11
ICF KAISER 2113 Emmorton Park Drive Suite 100 Edgewood, Maryland 21040 (410) 612-6350	WOODBRIDGE RESEARCH FACILITY
PREPARED CST / TASK NO: 66220	GEOLOGIC CROSS SECTION H-H'
CHECKED PT / ICF DWG NO:	
DATE 08-25-97 / WRF-XSN	



LEGEND:

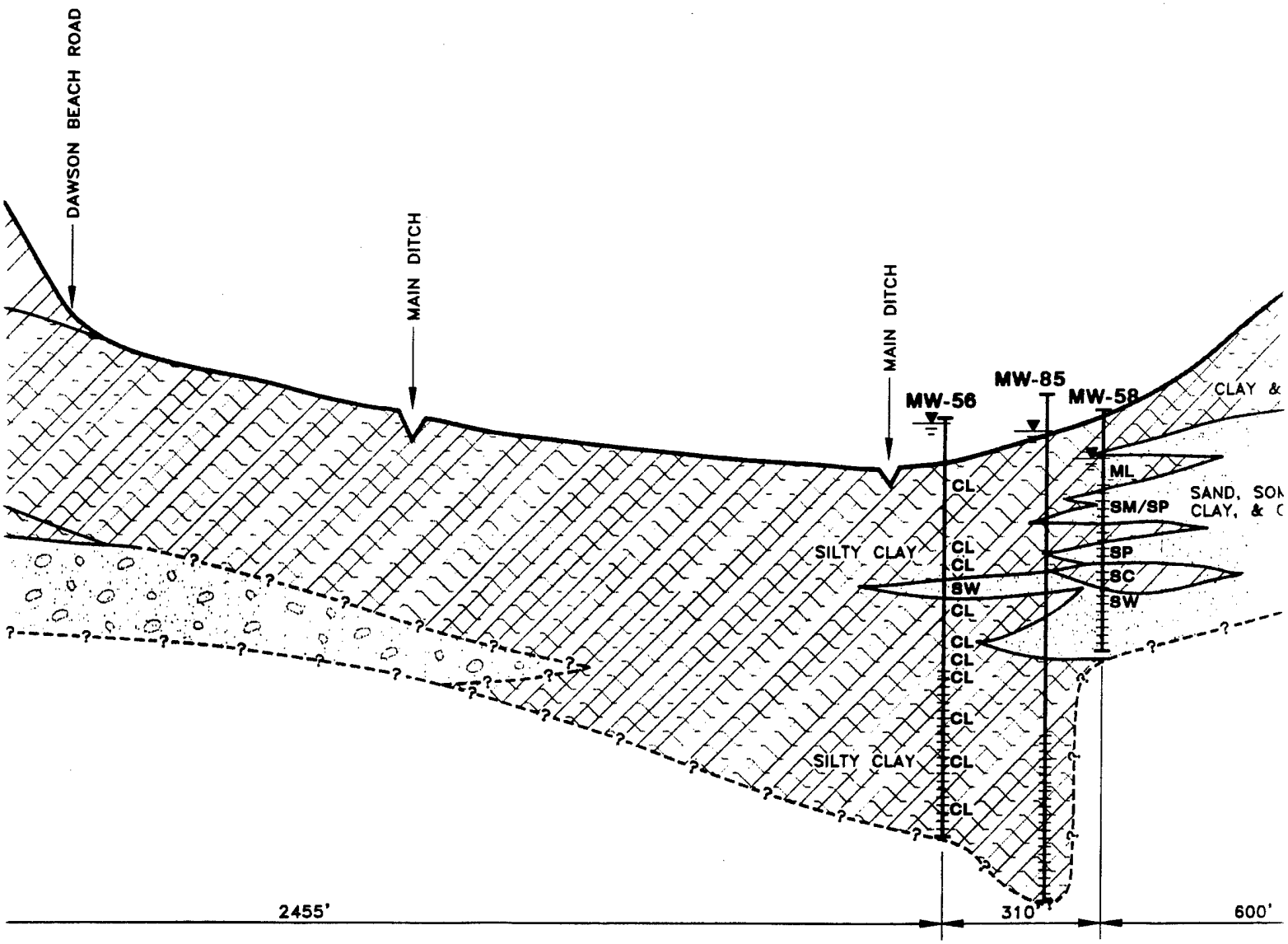
GROUNDWATER ELEVATION MEASURED JAN. 5, 1996

GRAVEL

SILT

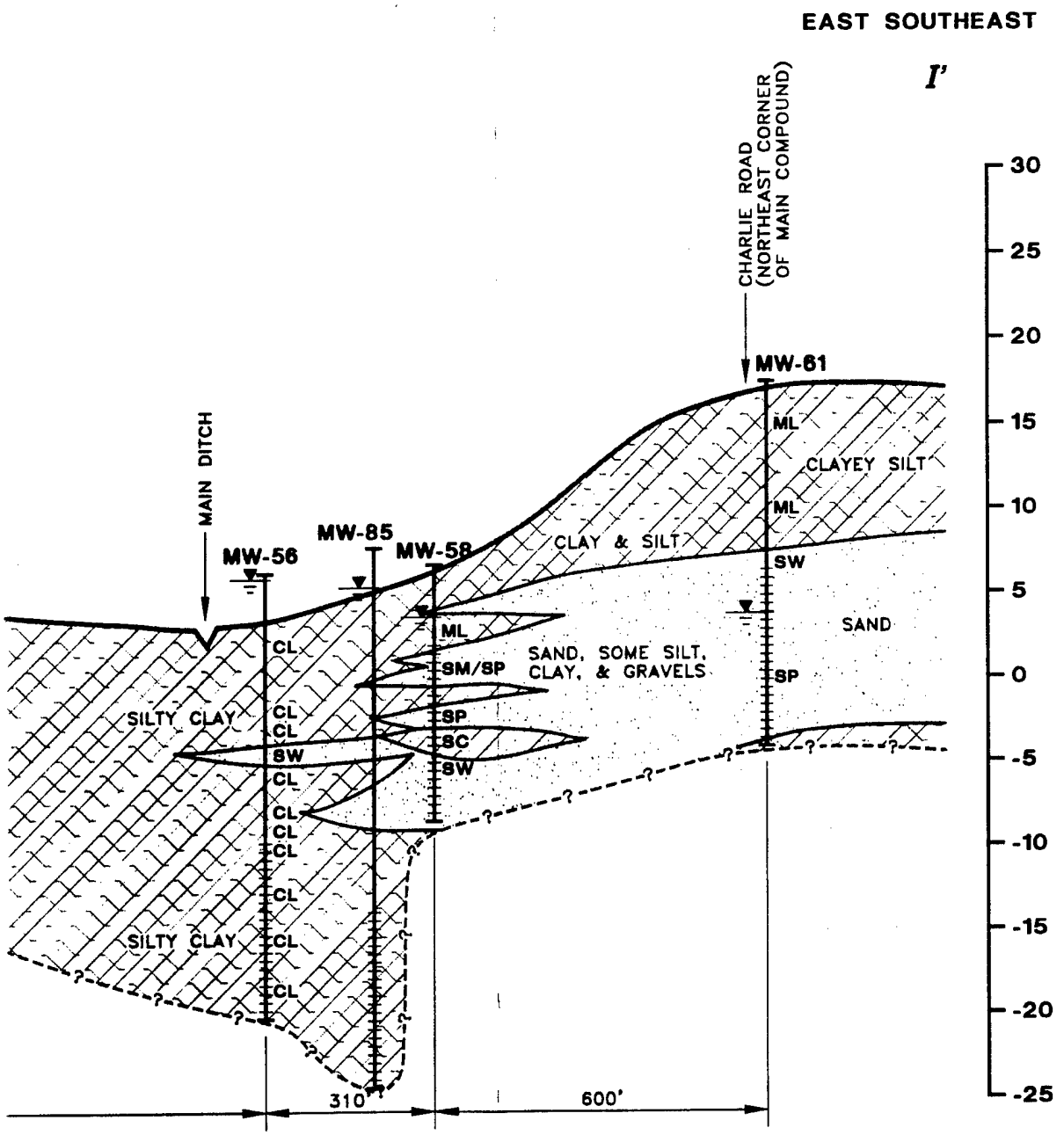
SAND

CLAY



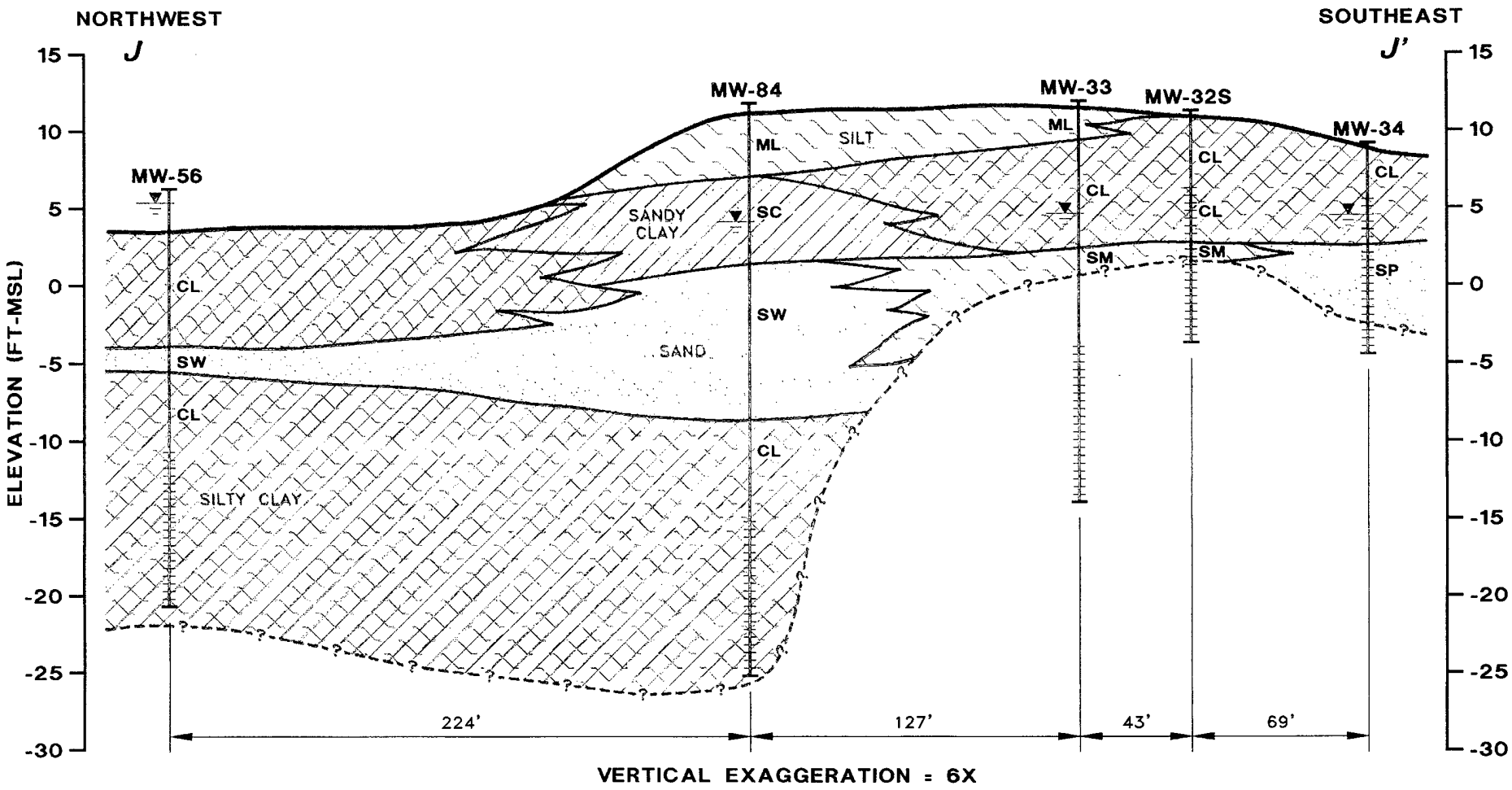
VERTICAL EXAGGERATION = 30X

ENVIR(	
CONTRACT NO. DACA3	
ICF KAISER	21 Su Ed (4
PREPARED CST	TAS
CHECKED PT	ICF
DATE 08-25-97	



US ARMY ENVIRONMENTAL CENTER

CONTRACT NO. DACA31-94-D-0064	FIGURE 2-12 WOODBRIDGE RESEARCH FACILITY
ICF KAISER 2113 Emmorton Park Drive Suite 100 Edgewood, Maryland 21040 (410) 612-6350	GEOLOGIC CROSS SECTION I-I'
PREPARED: CST	TASK NO: 66220
CHECKED: PT	ICF DWG NO: WRF-XSI
DATE: 08-25-97	



VERTICAL EXAGGERATION = 6X

LEGEND:

GROUNDWATER ELEVATION MEASURED JAN. 5, 1996

GRAVEL

SILT

SAND

CLAY

US ARMY ENVIRONMENTAL CENTER

CONTRACT NO. DACA31-94-D-0064

FIGURE 2-13

WOODBRIDGE RESEARCH FACILITY

ICF KAISER
2113 Emmorton Park Drive
Suite 100
Edgewood, Maryland 21040
(410) 612-6350

PREPARED CST

CHECKED PT

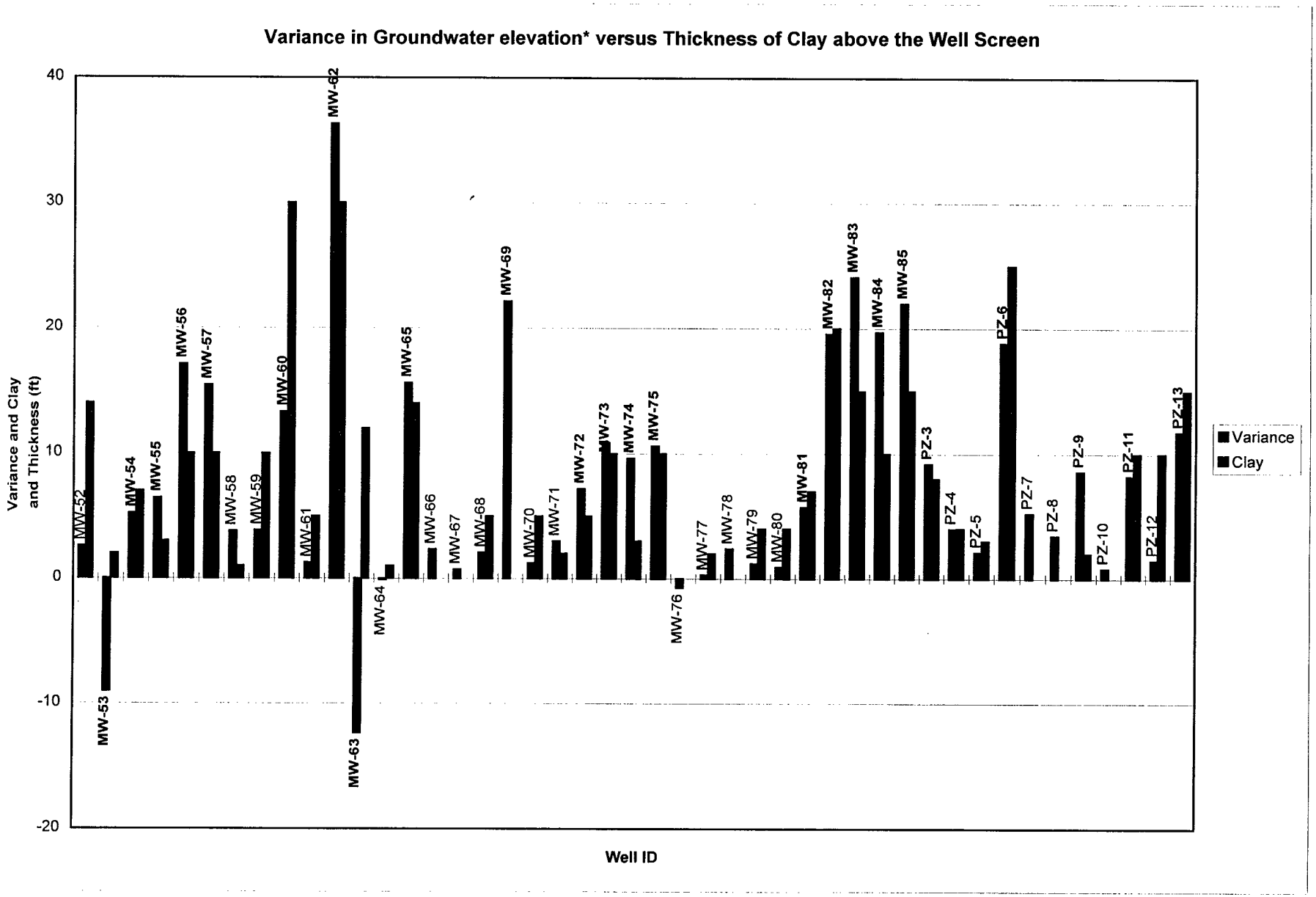
DATE 08-20-97

TASK NO: 66220

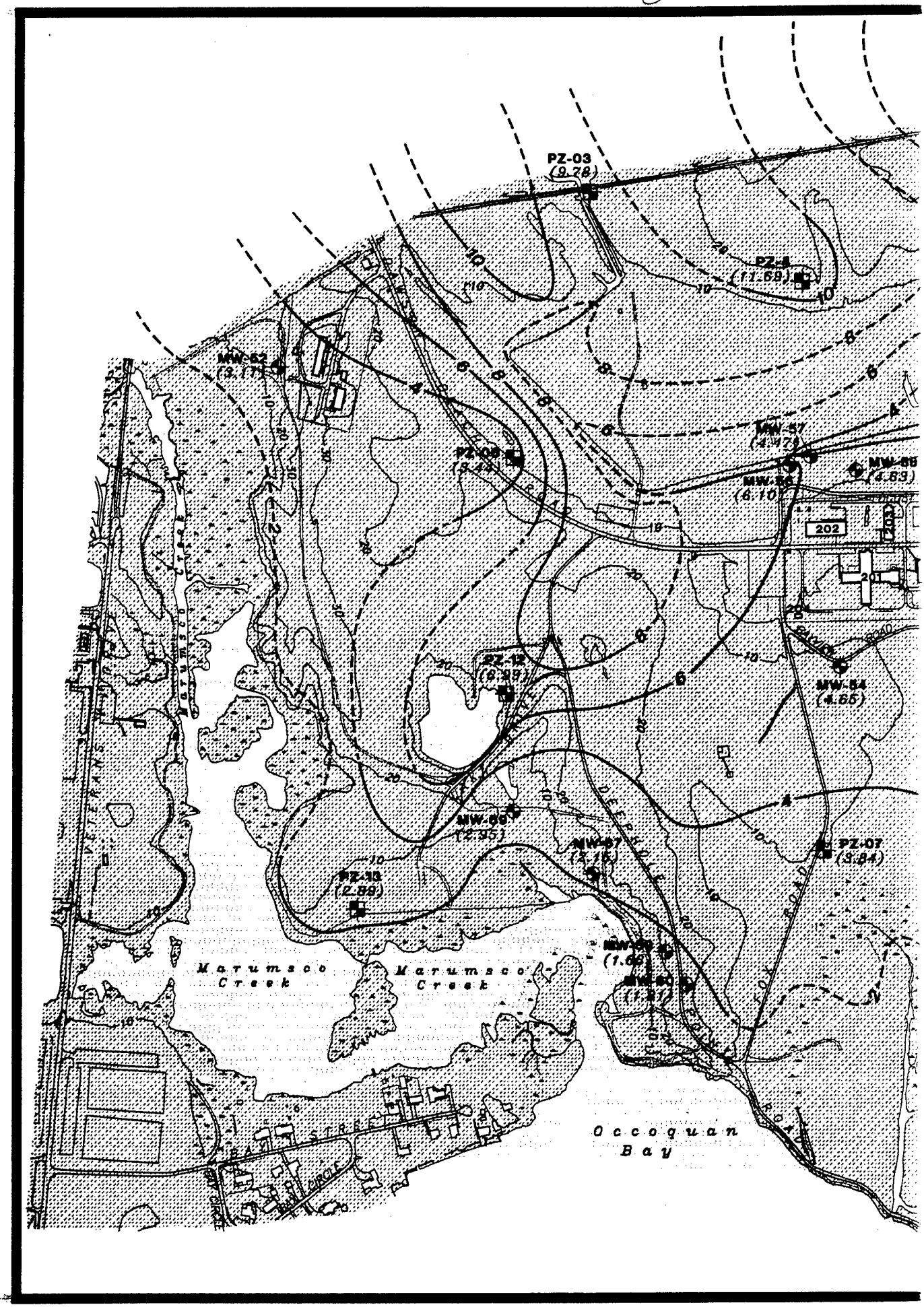
ICF DWG NO: WRF-XSJ

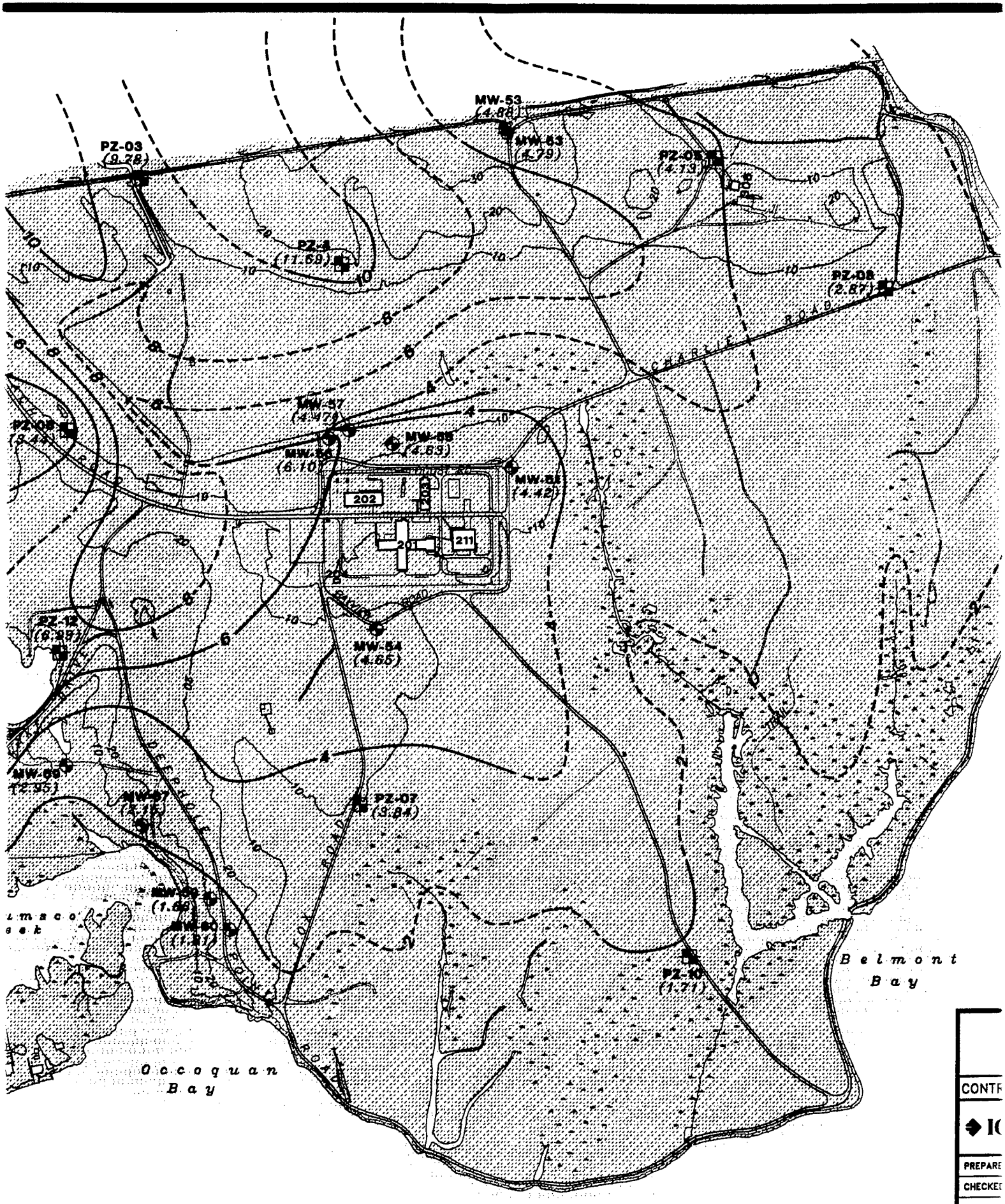
GEOLOGIC CROSS SECTION J-J'

Figure 2-14



* Variance is the difference in feet between the elevation at which water was first encountered during drilling and the stabilized groundwater elevation after well development.


PZ-03
(9.78)
PZ-4
(11.69)
MW-52
(3.11)
PZ-08
(8.44)
MW-57
(4.47)
MW-56
(4.63)
MW-55
(6.10)
202
PZ-12
(8.99)
MW-54
(4.65)
MW-66
(2.95)
MW-67
(3.15)
PZ-07
(3.84)
PZ-13
(2.89)
MW-68
(1.66)
MW-69
(1.21)
Marumsco
Creek
Marumsco
Creek
Occoquan
Bay
VETERANS
DEERPOINT
ROAD
STREET
CIRCLE

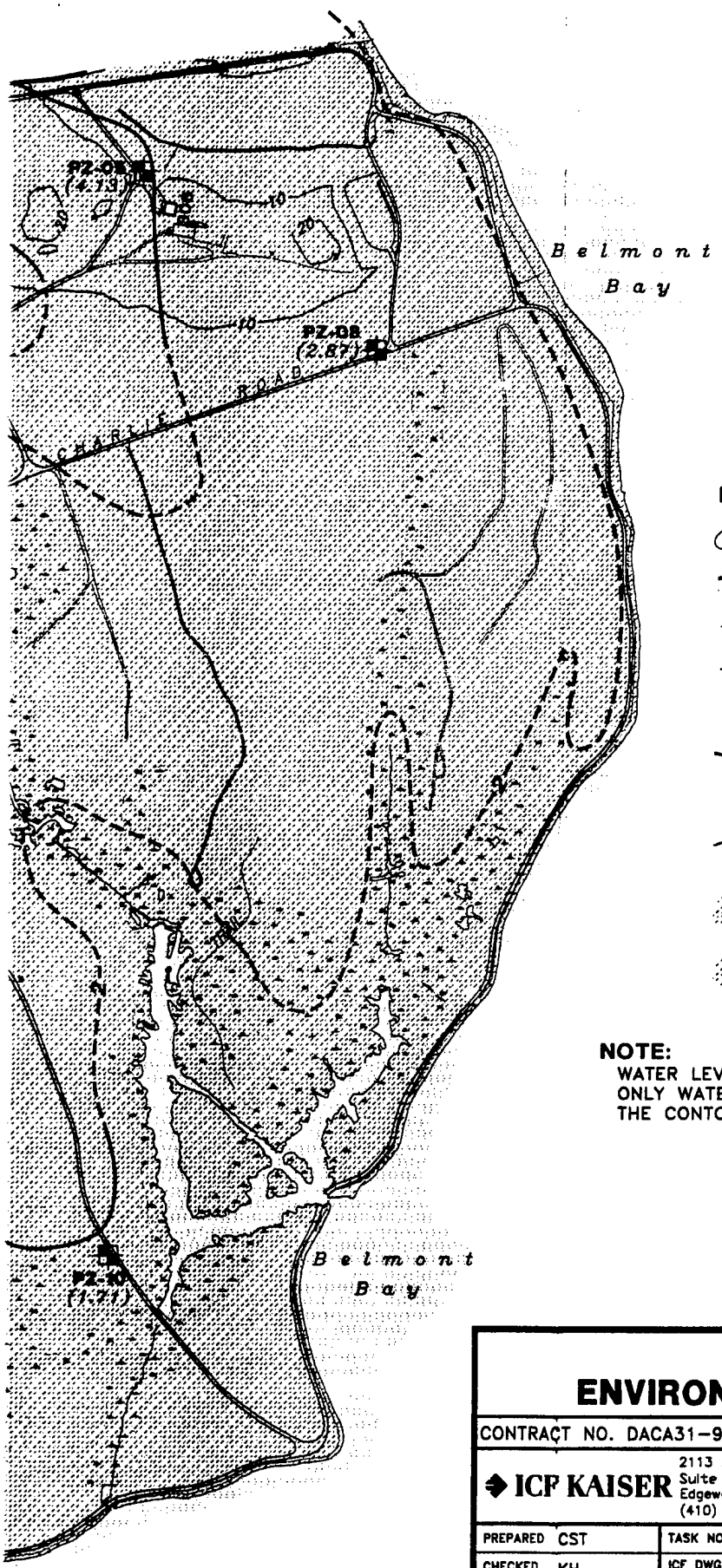


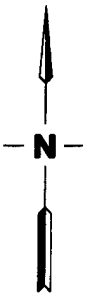
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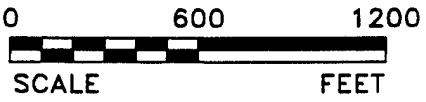




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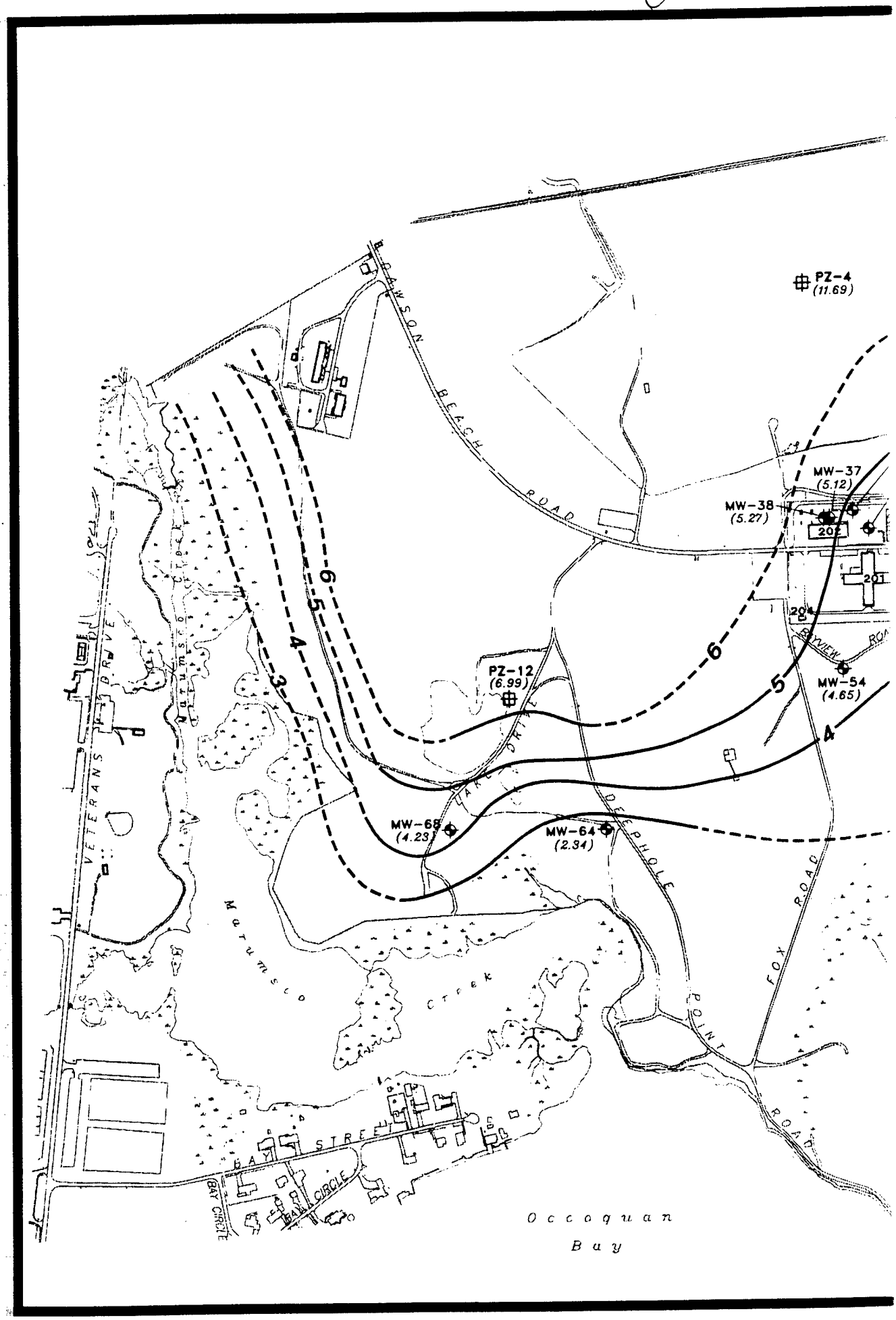
- WATER
- SWAMP
- MW-1 — MONITORING WELL LOCATION
- PZ-1 — PIEZOMETER LOCATION
- (1.71) — WATER LEVEL (FT. MSL)
- 4 — WATER TABLE CONTOUR (FT. MSL) (DASHED WHERE ESTIMATED)
- 20 — TOPOGRAPHIC CONTOUR (INTERVAL = 10')
- LAND AREA BELOW 10' TOPOGRAPHIC CONTOUR
- LAND AREA ABOVE 10' TOPOGRAPHIC CONTOUR

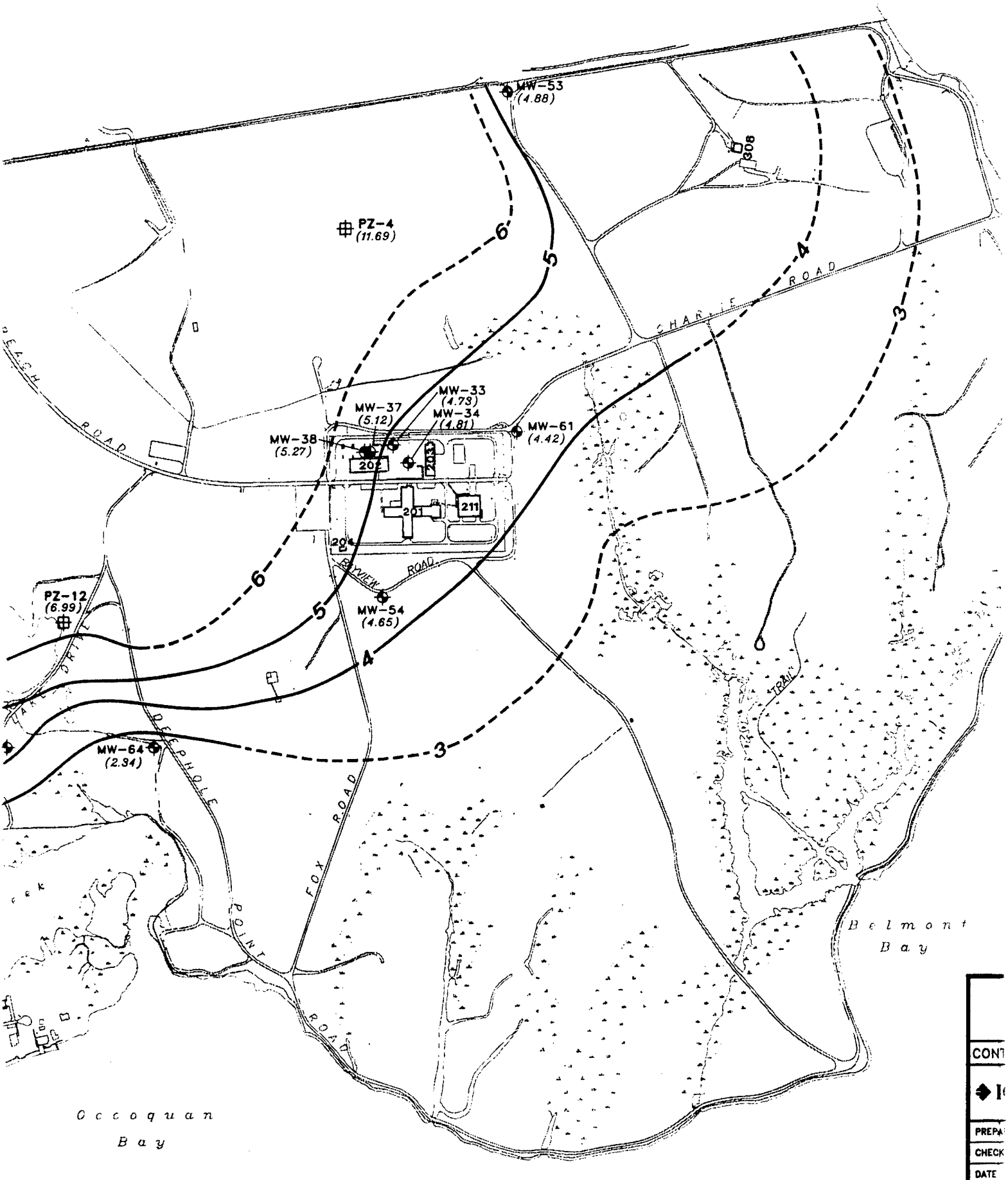
NOTE:
WATER LEVELS SHOWN ON THE MAP ARE THE ONLY WATER LEVELS USED TO CONSTRUCT THE CONTOURS.



US ARMY ENVIRONMENTAL CENTER

CONTRACT NO. DACA31-94-D-0064	FIGURE 2-15 WOODBRIDGE RESEARCH FACILITY
ICF KAISER 2113 Emmorton Park Drive Suite 100 Edgewood, Maryland 21040 (410) 612-6350	COMPOSITE WATER LEVEL CONTOUR MAP
PREPARED CST / TASK NO: 66220	
CHECKED KH / ICF DWG NO: WRF-IS05	
DATE 08-25-97	


PZ-4
(11.69)
DAWSON BEACH ROAD
MW-37
(5.12)
MW-38
(5.27)
202
201
204
BAYVIEW
PZ-12
(6.99)
MW-54
(4.65)
6
5
4
3
LAKE DRIVE
MW-65
(4.23)
MW-64
(2.34)
DEEPHOLE
VETERANS DRIVE
MATTAWOMAN CREEK
FOX POINT ROAD
BAY STREET
BAY CIRCLE
Occoquan
Bay

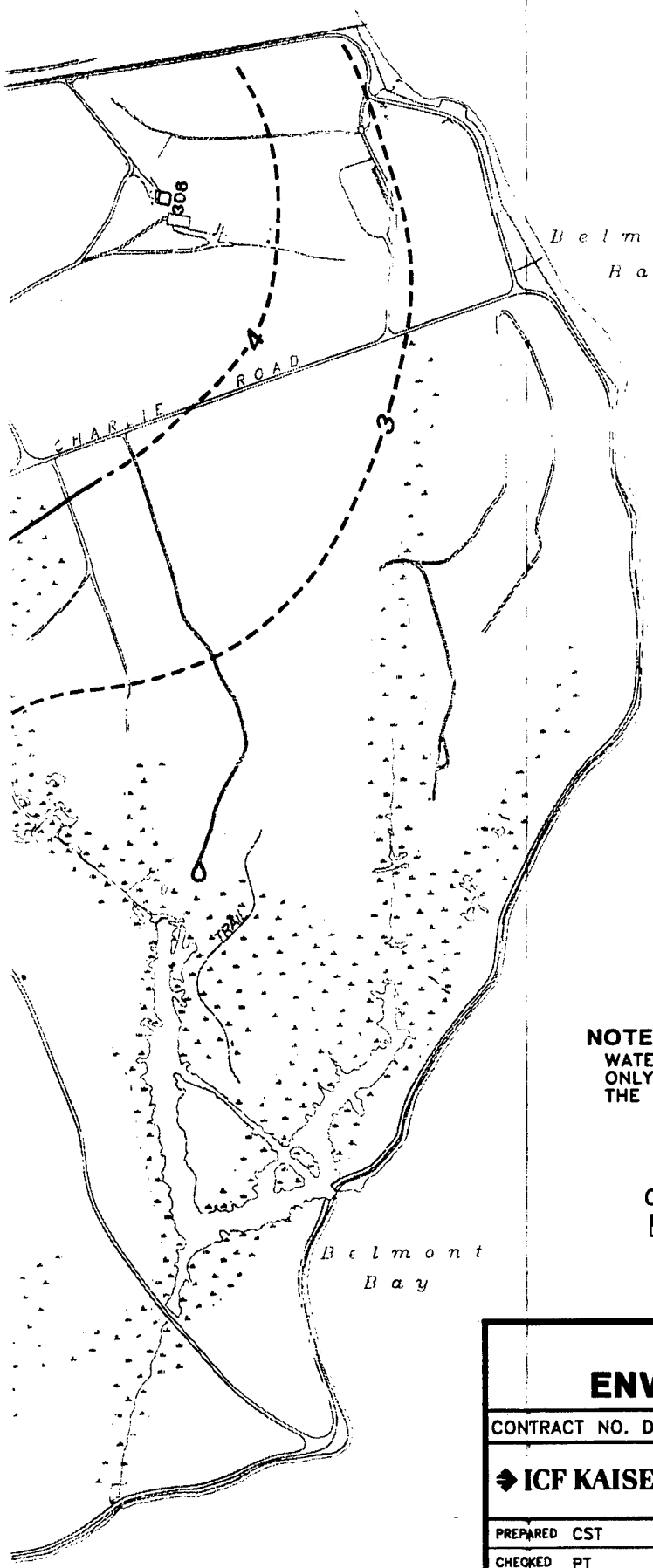


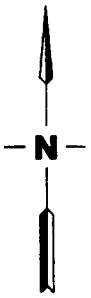
CONT

PREPA

CHECK

DATE





LEGEND:

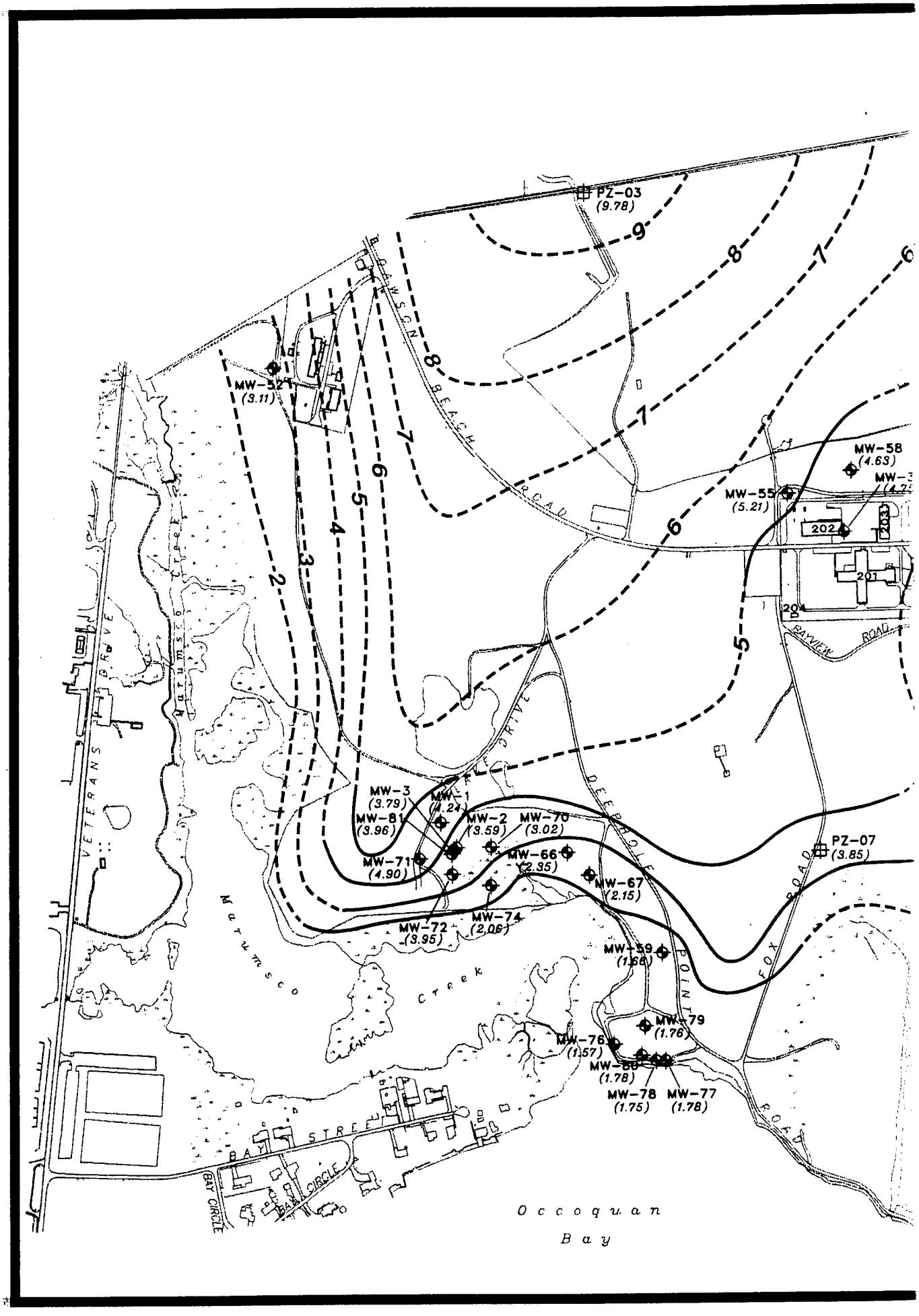
- ROAD
- FENCE
- WATER
- SWAMP
- MW-1 — MONITORING WELL LOCATION
- PZ-1 — PIEZOMETER LOCATION
- (1.23) — WATER LEVEL (FT. MSL)
- —5— POTENTIOMETRIC GROUNDWATER CONTOUR (DASHED WHERE ESTIMATED)

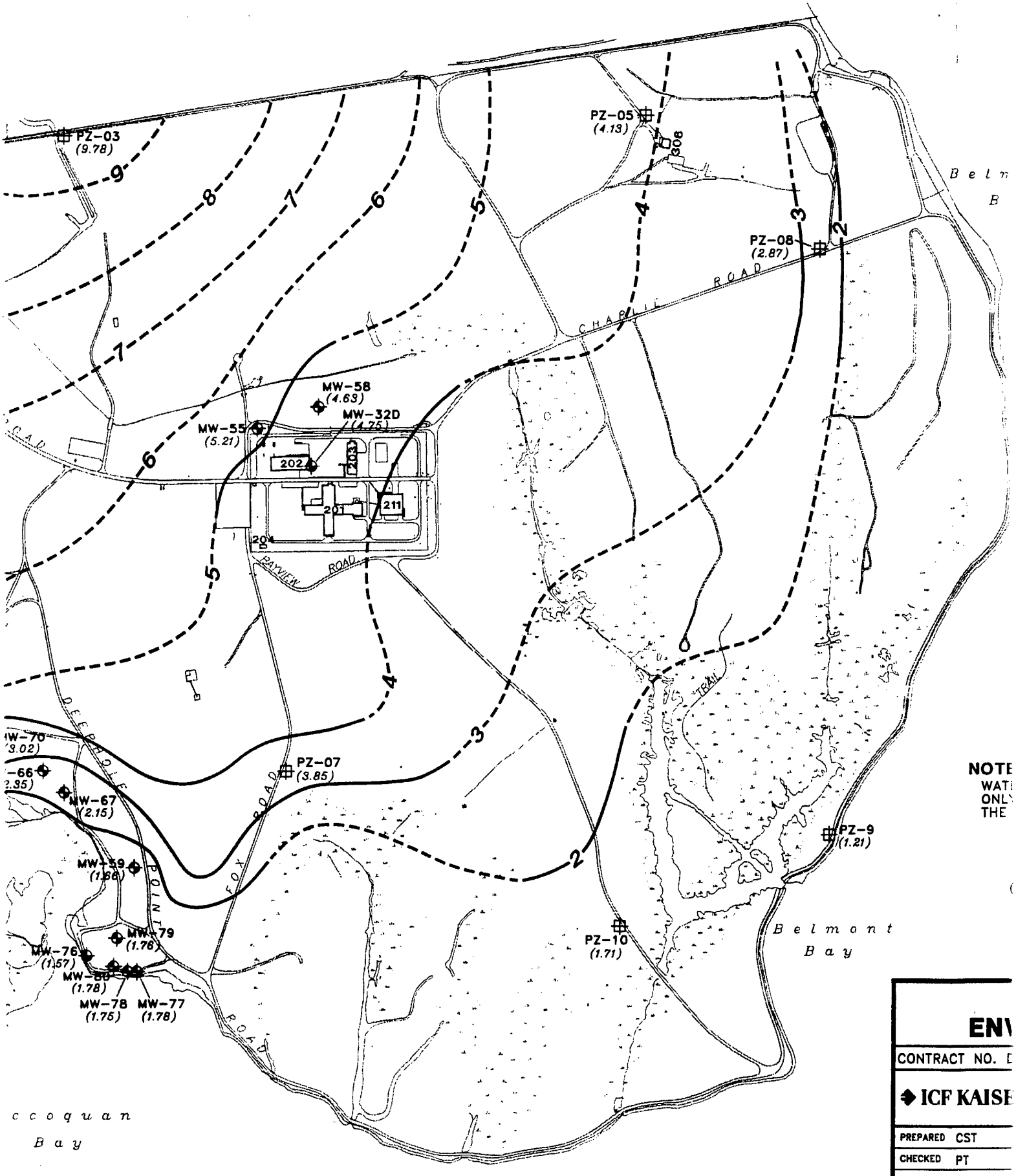
NOTE:
WATER LEVELS SHOWN ON THE MAP ARE THE ONLY WATER LEVELS USED TO CONSTRUCT THE CONTOURS.

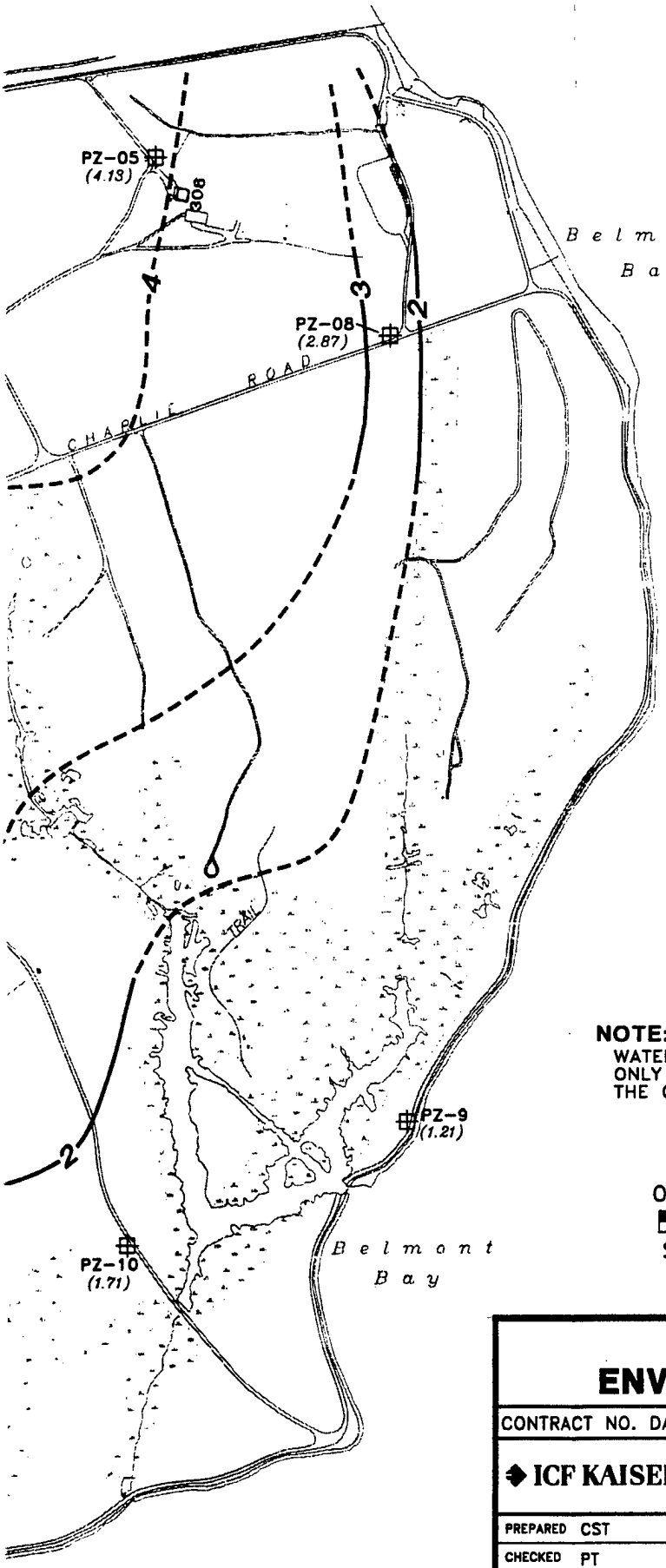
0 600 1200
SCALE FEET

US ARMY ENVIRONMENTAL CENTER

CONTRACT NO. DACA31-94-D-0064	FIGURE 2-16 WOODBRIDGE RESEARCH FACILITY
ICF KAISER 2113 Emmorton Park Drive Suite 100 Edgewood, Maryland 21040 (410) 612-6350	POTENTIOMETRIC CONTOURS OF WELLS WITH SCREEN MIDPOINT BETWEEN 10 to 0 FEET ABOVE MEAN SEA LEVEL
PREPARED CST	TASK NO: 68220
CHECKED PT	ICF DWG NO: POT-1
DATE 08-25-97	


PZ-03
(9.78)
MW-52
(3.11)
MW-58
(4.63)
MW-55
(5.21)
202
203
201
200
RAYVIEW ROAD
DAWSON BEACH ROAD
VETERANS DRIVE
DEER RIDGE DRIVE
FOX POINT ROAD
PZ-07
(3.85)
MW-3
(3.79)
MW-1
(4.24)
MW-81
(3.96)
MW-2
(3.59)
MW-70
(3.02)
MW-71
(4.90)
MW-66
(2.95)
MW-67
(2.15)
MW-72
(3.95)
MW-74
(2.06)
MW-59
(1.56)
MW-79
(1.76)
MW-76
(1.57)
MW-80
(1.78)
MW-78
(1.75)
MW-77
(1.78)
Mattawoman Creek
BAY STREET
BAY CIRCLE
Occoquan Bay
9
8
7
6
5
4
3
2


PZ-03
(9.78)
PZ-05
(4.13)
308
PZ-08
(2.87)
CHAPEL ROAD
MW-58
(4.69)
MW-32D
(4.75)
MW-55
(5.21)
202
203
201
211
204
BAYVIEW ROAD
DEERAGLE
MW-70
(3.02)
MW-66
(2.35)
MW-67
(2.15)
PZ-07
(3.85)
FOX POINT ROAD
MW-59
(1.66)
MW-79
(1.76)
MW-76
(1.57)
MW-80
(1.78)
MW-78
(1.75)
MW-77
(1.78)
PZ-10
(1.71)
PZ-9
(1.21)
TRAIL
Belmont Bay
Occoquan Bay
9
8
7
6
5
4
3
2
NOTE
WAT
ONL
THE
ENV
CONTRACT NO.
ICF KAISE
PREPARED CST
CHECKED PT
DATE 08-25-97



N

LEGEND:

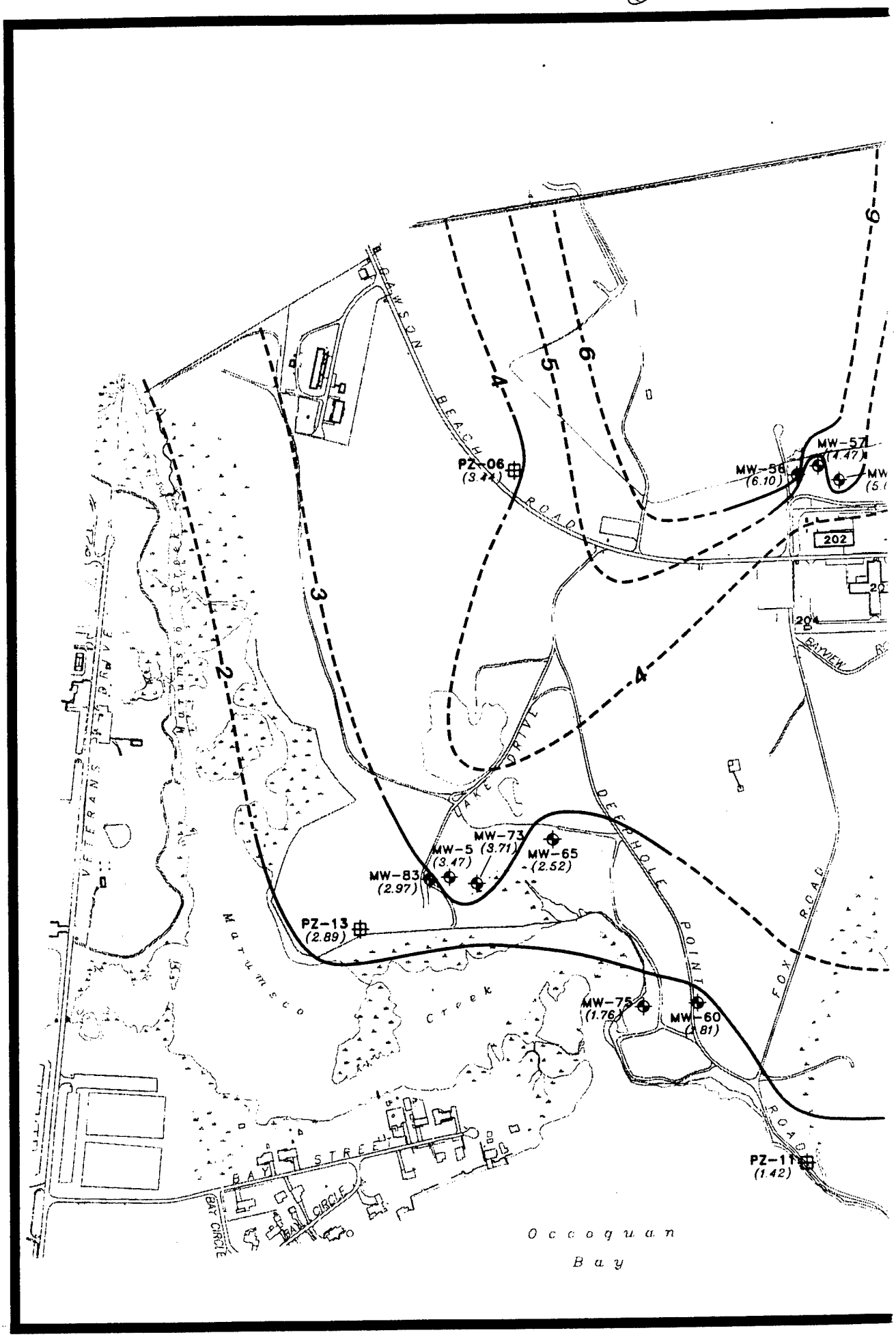
- ROAD
- FENCE
- WATER
- SWAMP
- MW-1 — MONITORING WELL LOCATION
- PZ-1 — PIEZOMETER LOCATION
- (4.23) — WATER LEVEL (FT. MSL)
- 5 — POTENTIOMETRIC GROUNDWATER CONTOUR (DASHED WHERE ESTIMATED)

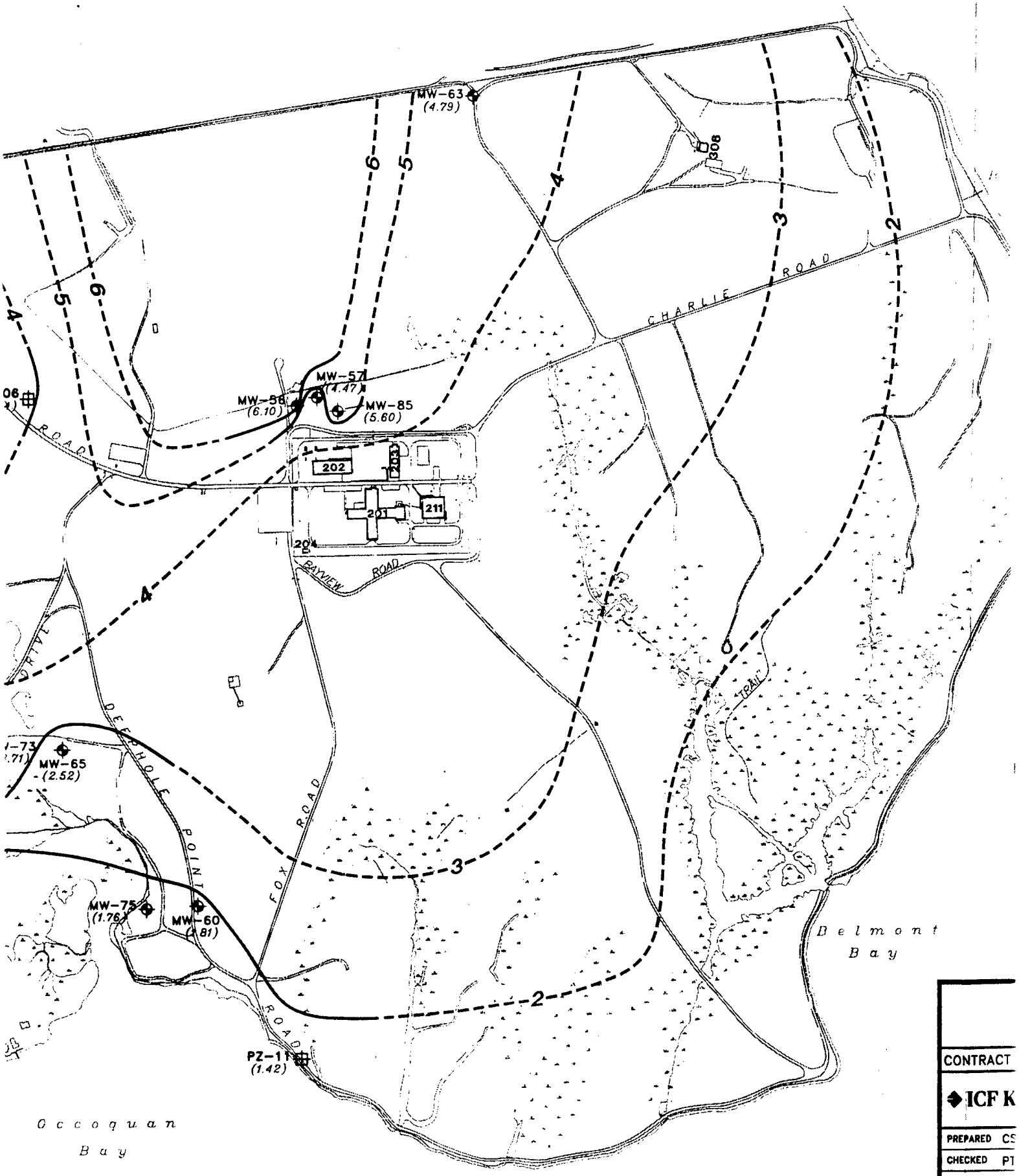
NOTE:
WATER LEVELS SHOWN ON THE MAP ARE THE ONLY WATER LEVELS USED TO CONSTRUCT THE CONTOURS.

0 600 1200
SCALE FEET

US ARMY ENVIRONMENTAL CENTER

CONTRACT NO. DACA31-94-D-0064	FIGURE 2-17
ICF KAISER — 2113 Emmorton Park Drive Suite 100 Edgewood, Maryland 21040 (410) 612-6350	WOODBRIDGE RESEARCH FACILITY
PREPARED CST / TASK NO: 66220	POTENTIOMETRIC CONTOURS OF WELLS WITH SCREEN MIDPOINT BETWEEN 0 to -10 FEET ABOVE MEAN SEA LEVEL
CHECKED PT / ICF DWG NO: POT-2	
DATE 08-25-97	


9
6
5
4
3
2
4
PZ-06
(3.42)
MW-56
(6.10)
MW-57
(4.47)
202
BAYVIEW
LAKE DRIVE
DEEPHOLE POINT ROAD
FOX ROAD
MW-73
(3.71)
MW-5
(3.47)
MW-65
(2.52)
MW-83
(2.97)
PZ-13
(2.89)
MW-75
(1.76)
MW-60
(.81)
PZ-11
(1.42)
VETERANS
Marumsco
Creek
BAY STREET
BAY CIRCLE
Occoquan
Bay



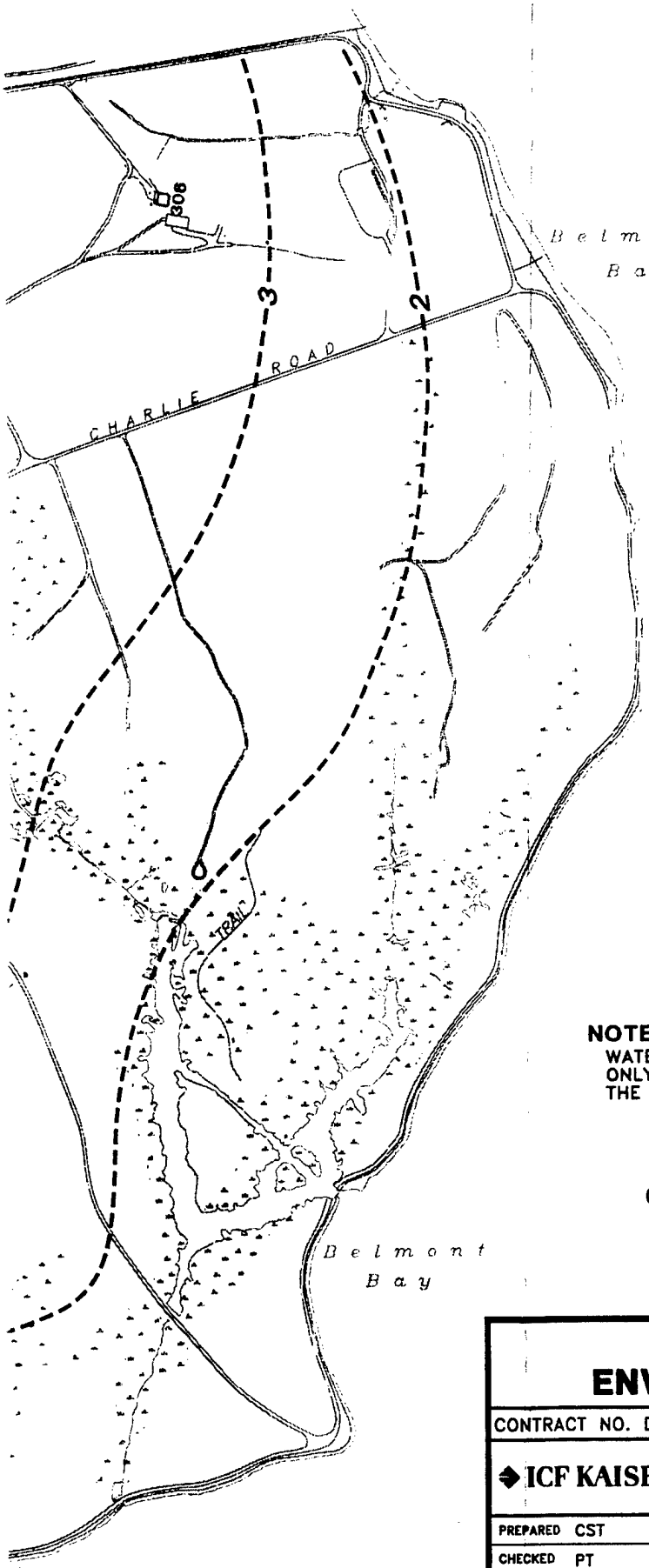
CONTRACT

◆ICF K

PREPARED CS

CHECKED PT

DATE 08-2

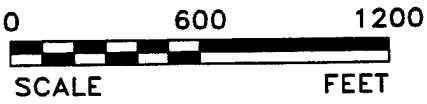




LEGEND:

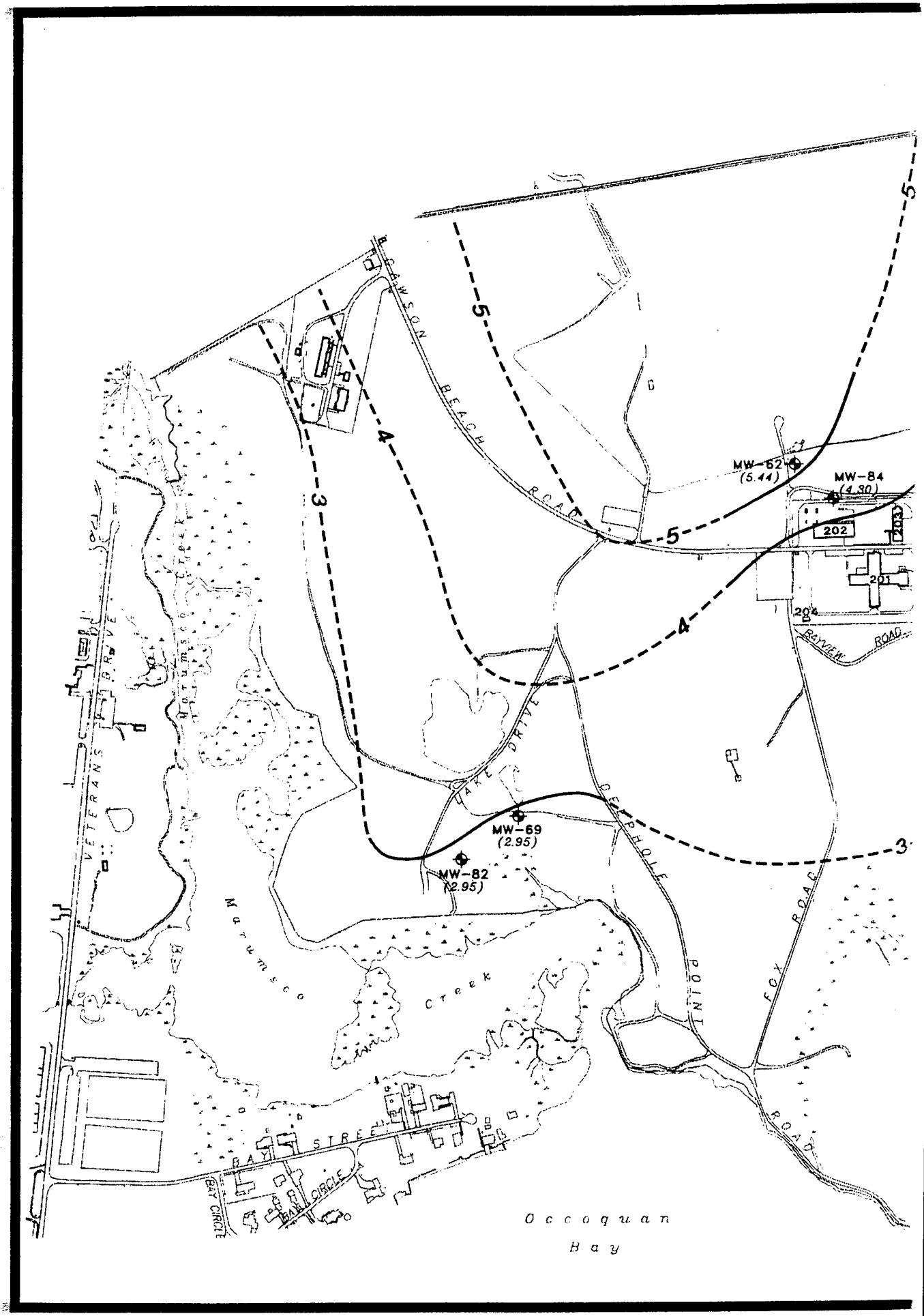
- ROAD
- FENCE
- WATER
- SWAMP
- MW-1 — MONITORING WELL LOCATION
- PZ-1 — PIEZOMETER LOCATION
- (4.23) — WATER LEVEL (FT. MSL)
- —5— POTENTIOMETRIC GROUNDWATER CONTOUR (DASHED WHERE ESTIMATED)

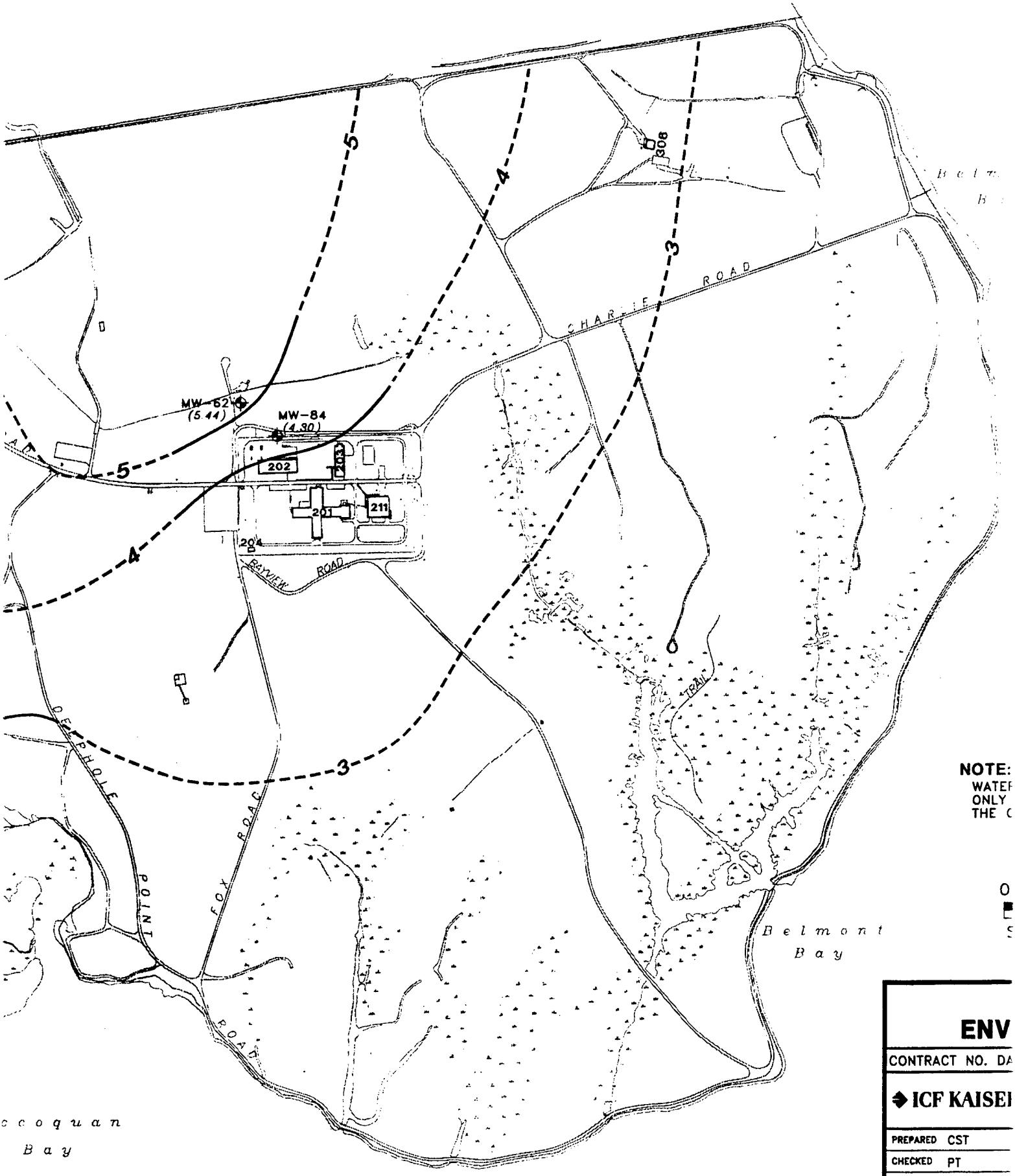
NOTE:
WATER LEVELS SHOWN ON THE MAP ARE THE ONLY WATER LEVELS USED TO CONSTRUCT THE CONTOURS.



US ARMY ENVIRONMENTAL CENTER

CONTRACT NO. DACA31-94-D-0064	FIGURE 2-18 WOODBRIDGE RESEARCH FACILITY
ICF KAISER 2113 Emmorton Park Drive Suite 100 Edgewood, Maryland 21040 (410) 612-6350	**POTENTIOMETRIC CONTOURS OF WELLS WITH SCREEN MIDPOINT BETWEEN -10 to -20 FEET ABOVE MEAN SEA LEVEL**
PREPARED CST	TASK NO: 66220
CHECKED PT	ICF DWG NO: POT-3
DATE 08-25-97	


5
4
3
MW-62
(5.44)
MW-84
(4.30)
202
203
201
204
MW-69
(2.95)
MW-82
(2.95)
Occoquan
Bay



NOTE:
WATER
ONLY
THE

ENV

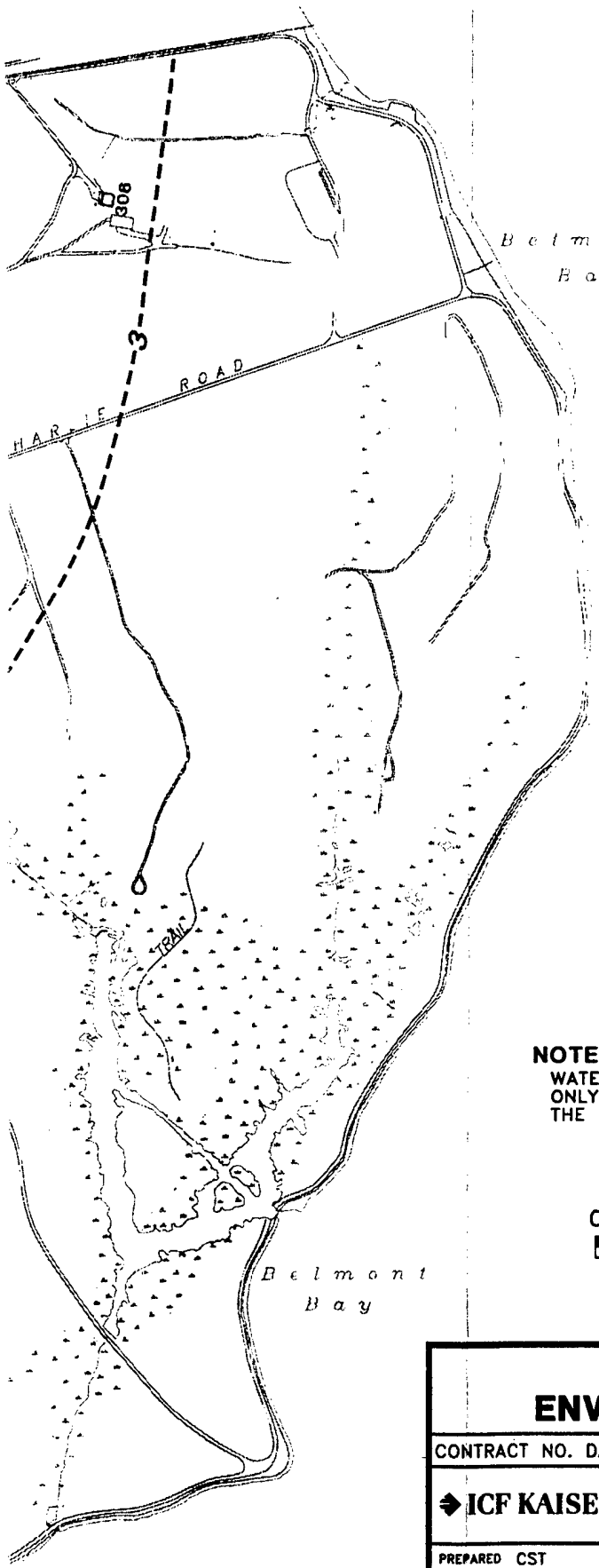
CONTRACT NO. DA

ICF KAISER

PREPARED CST

CHECKED PT

DATE 08-25-97



N

LEGEND:

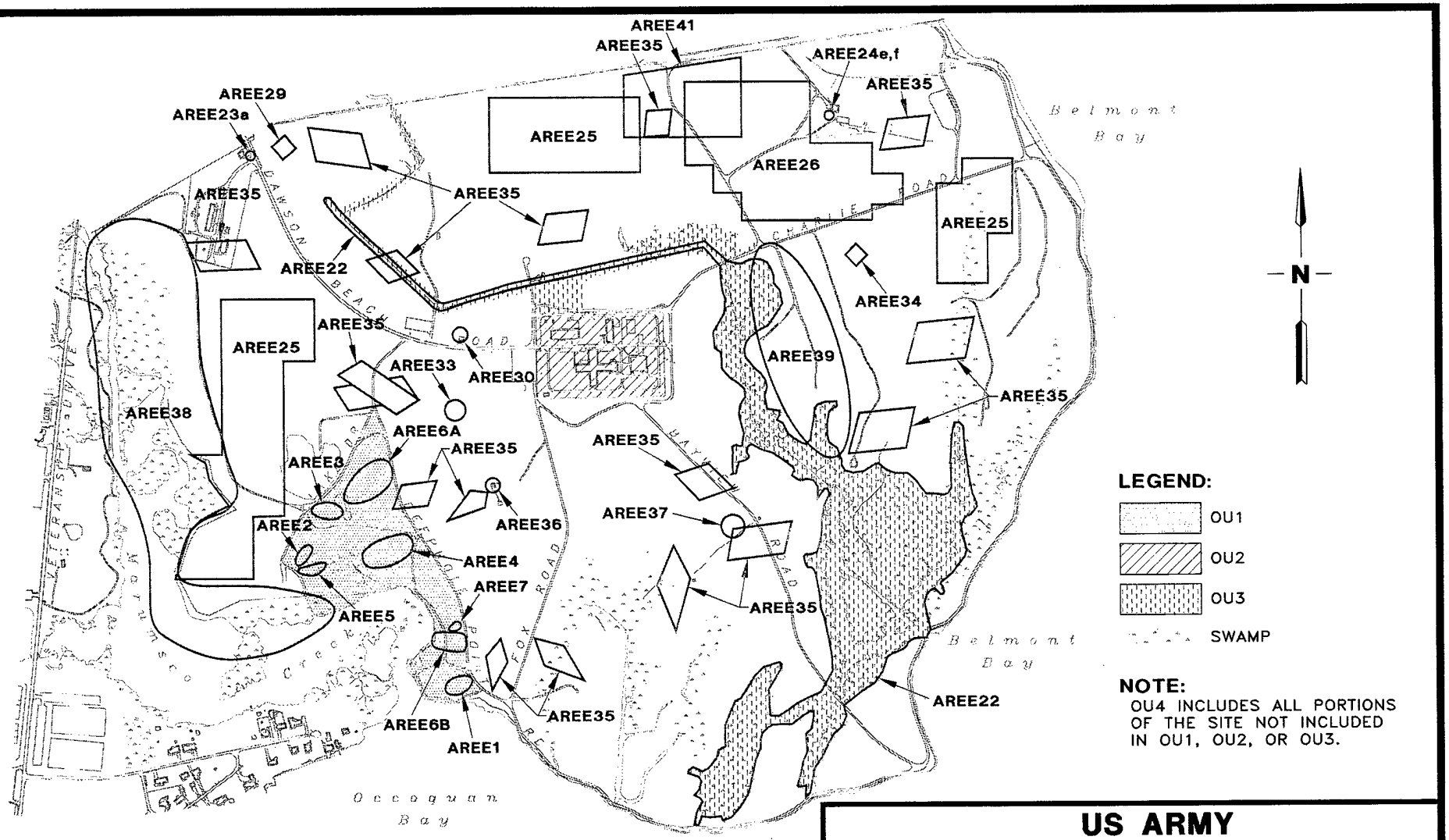
- ROAD
- FENCE
- WATER
- SWAMP
- ⊕ MW-1 — MONITORING WELL LOCATION
- (4.23) — WATER LEVEL (FT. MSL)
- —5— POTENTIOMETRIC GROUNDWATER CONTOUR (DASHED WHERE ESTIMATED)

NOTE:
WATER LEVELS SHOWN ON THE MAP ARE THE ONLY WATER LEVELS USED TO CONSTRUCT THE CONTOURS.

0 600 1200
SCALE FEET

US ARMY ENVIRONMENTAL CENTER

CONTRACT NO. DACA31-94-D-0064		FIGURE 2-19 WOODBRIDGE RESEARCH FACILITY
ICF KAISER	2113 Emmorton Park Drive Suite 100 Edgewood, Maryland 21040 (410) 612-6350	POTENTIOMETRIC CONTOURS OF WELLS WITH SCREEN MIDPOINT BETWEEN -20 to -30 FEET ABOVE MEAN SEA LEVEL
PREPARED CST	TASK NO: 66220	
CHECKED PT	ICF DWG NO: POT-4	
DATE 08-25-97		



US ARMY ENVIRONMENTAL CENTER

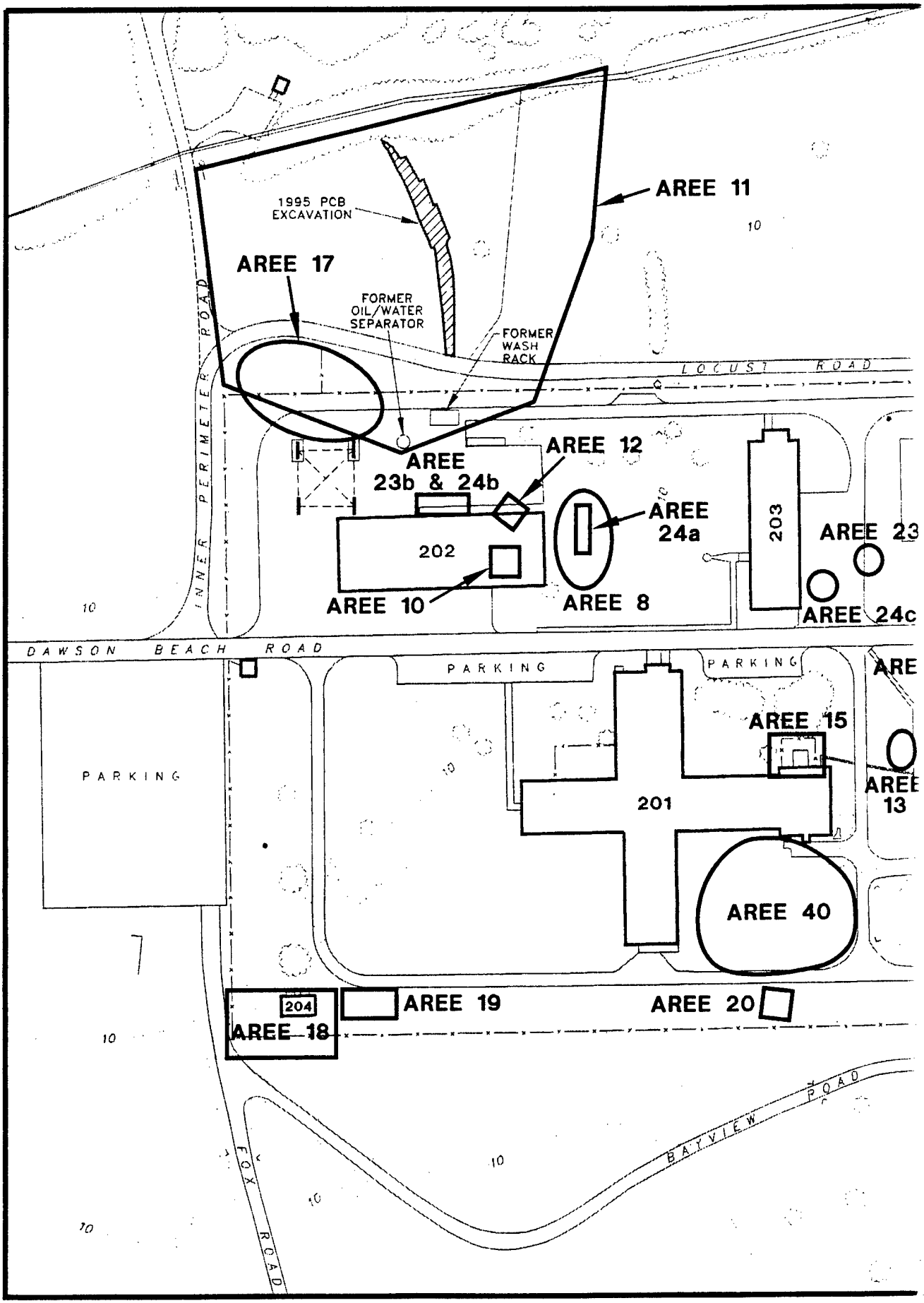
CONTRACT NO. DACA31-94-D-0064

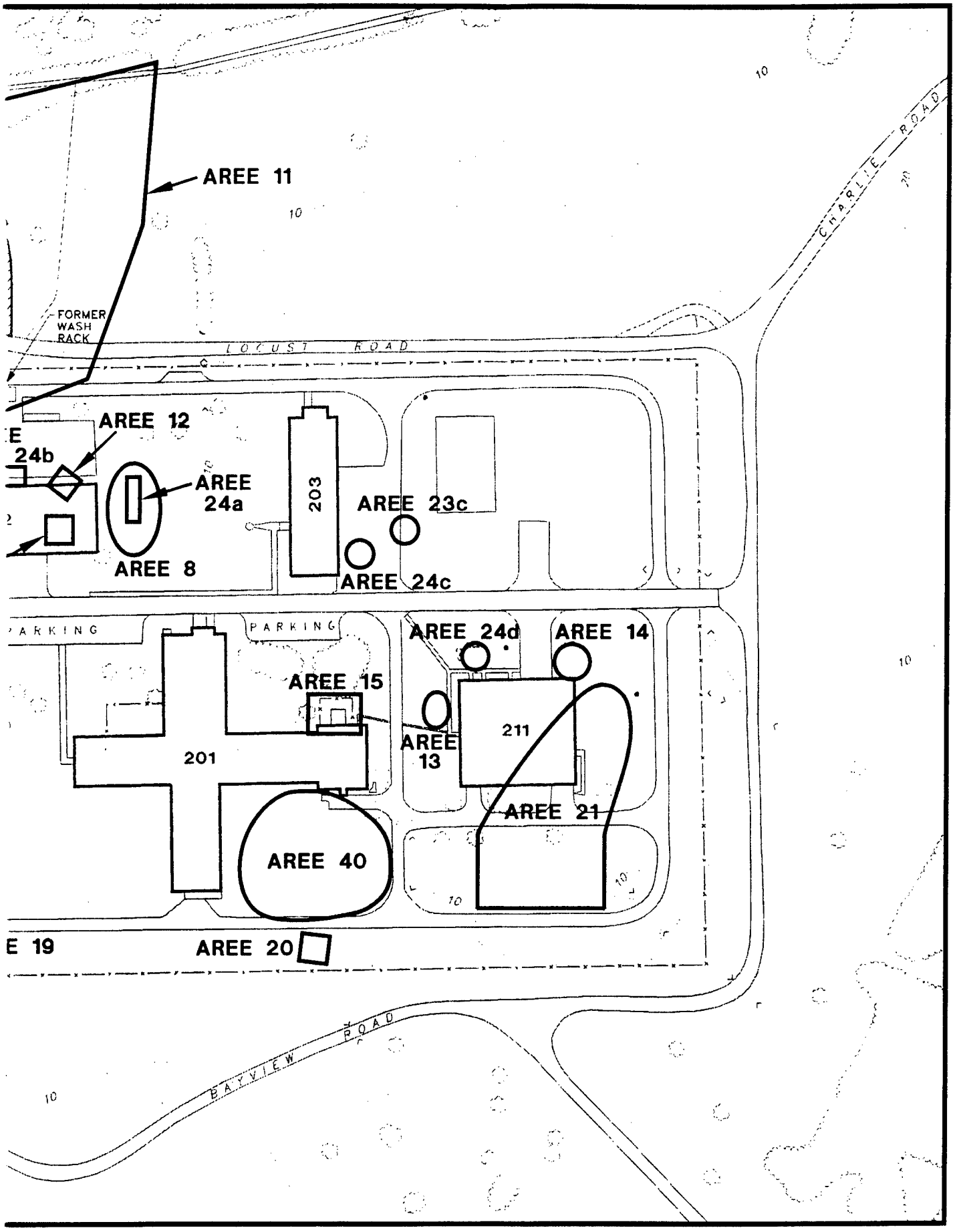
FIGURE 2-20
WOODBRIDGE RESEARCH FACILITY

ICF KAISER
1301 Continental Drive
Suite 101
Abingdon, Maryland 21009
(410) 612-6350

PREPARED CST	TASK NO: 66220
CHECKED PT	ICF DWG NO: AR-OULOC
DATE 08-01-97	

LOCATIONS OF AREES AND OPERABLE UNITS AT WRF


AREE 11
1995 PCB EXCAVATION
AREE 17
FORMER OIL/WATER SEPARATOR
FORMER WASH RACK
LOCUST ROAD
INNER PERIMETER ROAD
AREE 12
AREE 23b & 24b
AREE 24a
202
203
AREE 23
AREE 10
AREE 8
AREE 24c
DAWSON BEACH ROAD
PARKING
PARKING
PARKING
AREE 15
201
AREE 13
AREE 40
204
AREE 18
AREE 19
AREE 20
FOX ROAD
BAYVIEW ROAD
10



CONTRACT

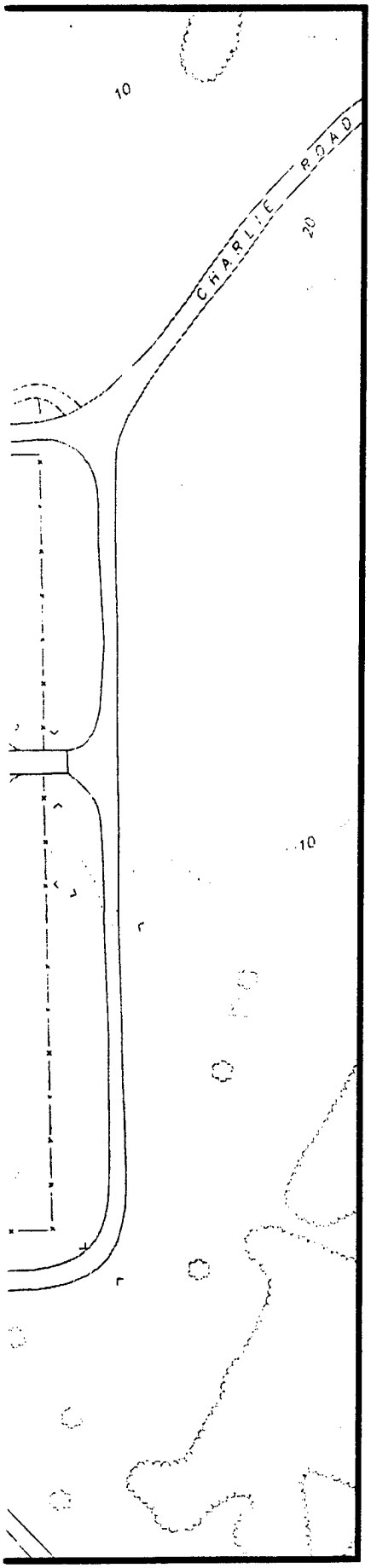
ICF

PREPARED

CHECKED

DATE 08-

(3)



LEGEND:

ROAD

FENCE

WATER

TREE LINE

10 TOPOGRAPHIC CONTOUR (CONTOUR INTERVAL = 10 FT.)

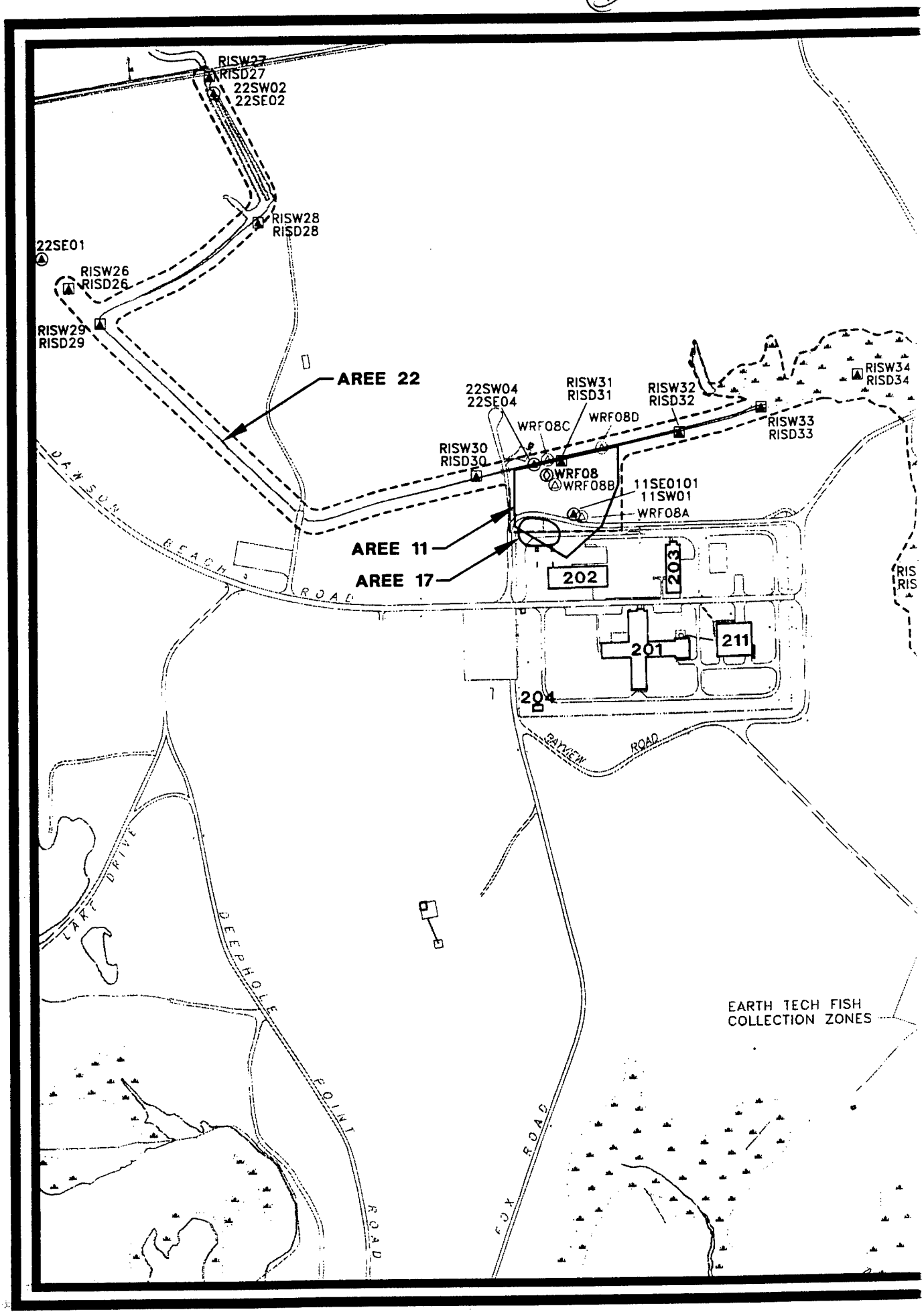
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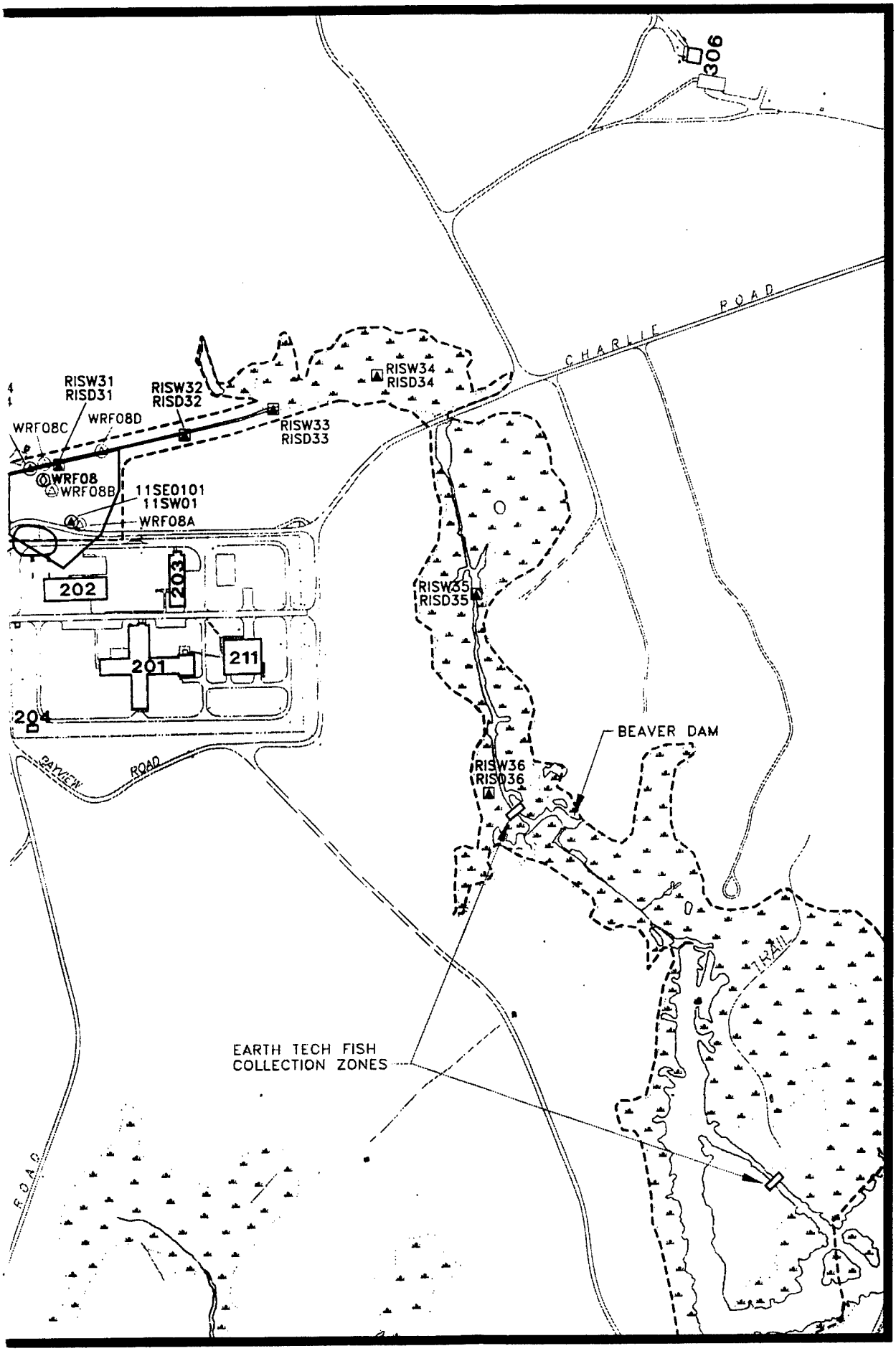
0 120 240

SCALE FEET

US ARMY ENVIRONMENTAL CENTER

CONTRACT NO. DACA31-94-D-0064	FIGURE 2-21
ICF KAISER 2113 Emmorton Park Drive Suite 100 Edgewood, Maryland 21040 (410) 612-6350	WOODBRIDGE RESEARCH FACILITY
PREPARED CST / TASK NO: 68220	LOCATIONS OF AREES AT MAIN FACILITY COMPUND
CHECKED PT / ICF DWG NO:	
DATE 08-06-97	FACAREE


RISW27
RISD27
22SW02
22SE02
RISW28
RISD28
22SE01
RISW26
RISD26
RISW29
RISD29
AREE 22
22SW04
22SE04
RISW31
RISD31
RISW32
RISD32
RISW34
RISD34
RISW33
RISD33
WRF08C
WRF08D
RISW30
RISD30
WRF08
WRF08B
11SE0101
11SW01
WRF08A
AREE 11
AREE 17
DAWSON BEACH ROAD
202
203
201
211
204
RAYVIEW ROAD
LAKE DRIVE
DEEPHOLE POINT ROAD
FOX ROAD
EARTH TECH FISH
COLLECTION ZONES



LEG

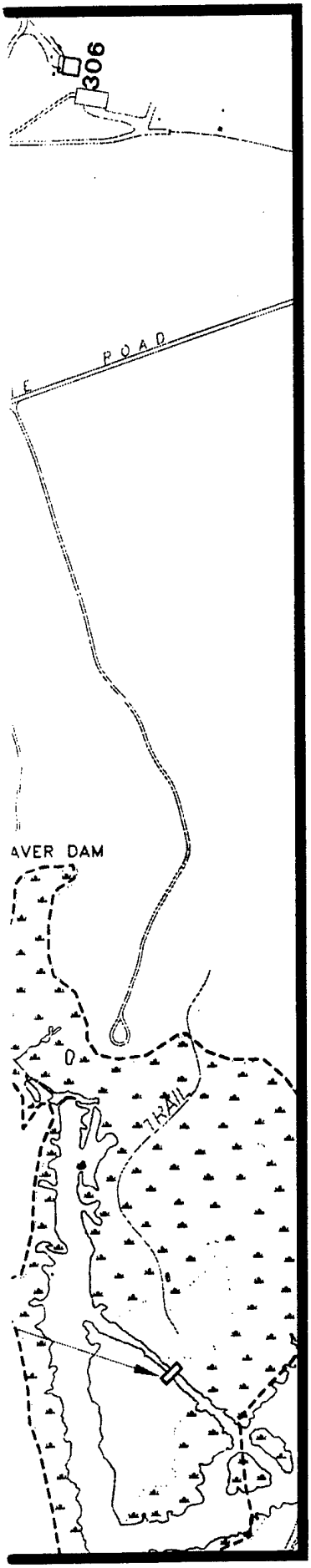
CONTRACT

ICF KA

PREPARED CST

CHECKED PT

DATE 10-27



LEGEND:

- 1995 RI SURFACE WATER/SEDIMENT SAMPLE LOCATION
- SI SURFACE WATER/SEDIMENT SAMPLE LOCATION
- VADEQ SURFACE WATER/SEDIMENT SAMPLE LOCATION
- VADEQ STORM WATER SAMPLE LOCATION
- LOCATION OF OU3
- ROAD
- FENCE
- WATER
- SWAMP

N

0 400 800

SCALE FEET

US ARMY ENVIRONMENTAL CENTER

CONTRACT NO. DACA31-94-D-0064

FIGURE 2-22

WOODBRIDGE RESEARCH FACILITY

ICF KAISER
2113 Emmorton Park Drive
Suite 100
Edgewood, Maryland 21040
(410) 612-6350

PREPARED CST

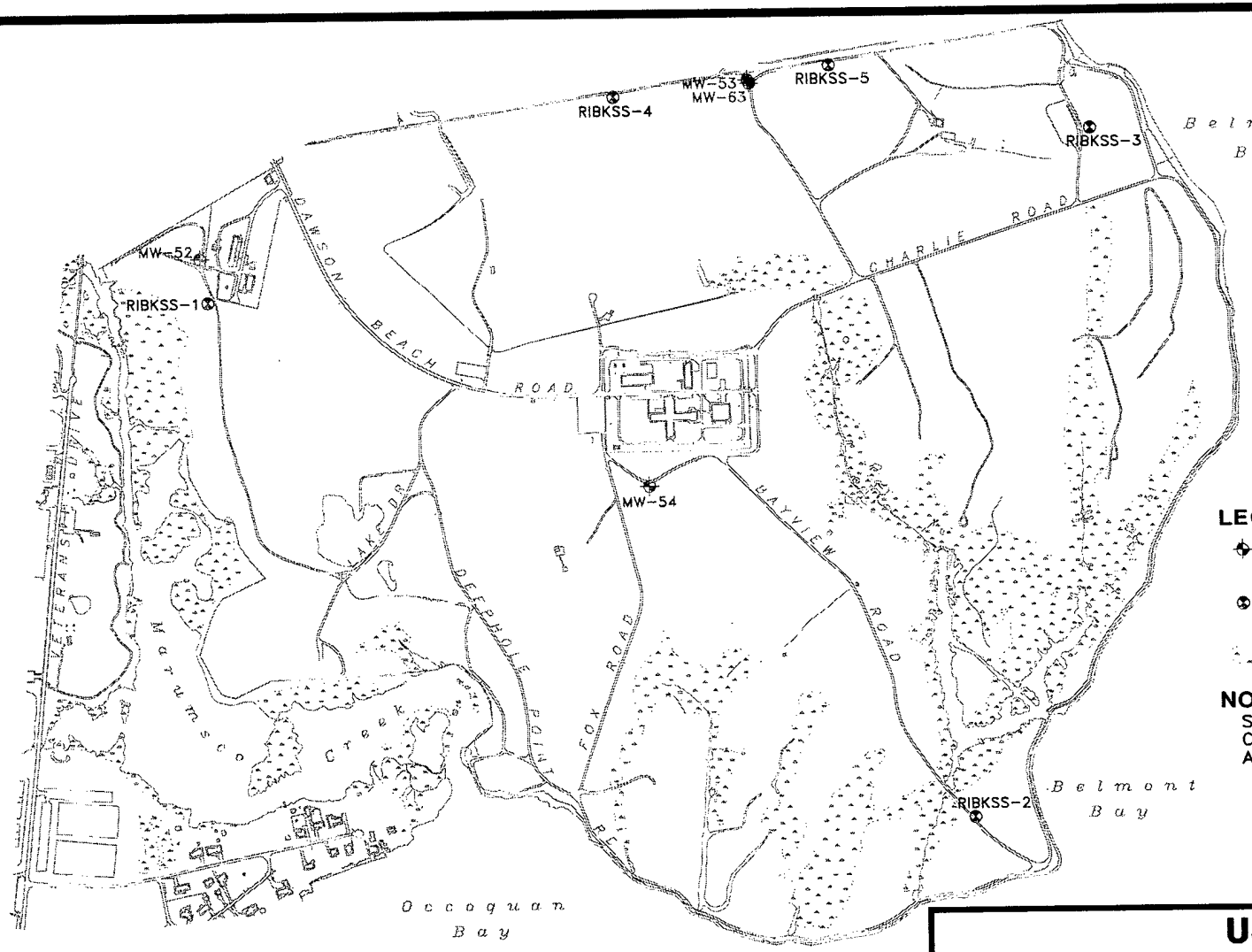
TASK NO: 66220

CHECKED PT

ICF DWG NO: OU3-SMP

DATE 10-27-97

SAMPLE LOCATIONS ASSOCIATED WITH THE UPPER REACHES OF THE MAIN DITCH AND MAIN COMPOUND AREA



LEGEND:

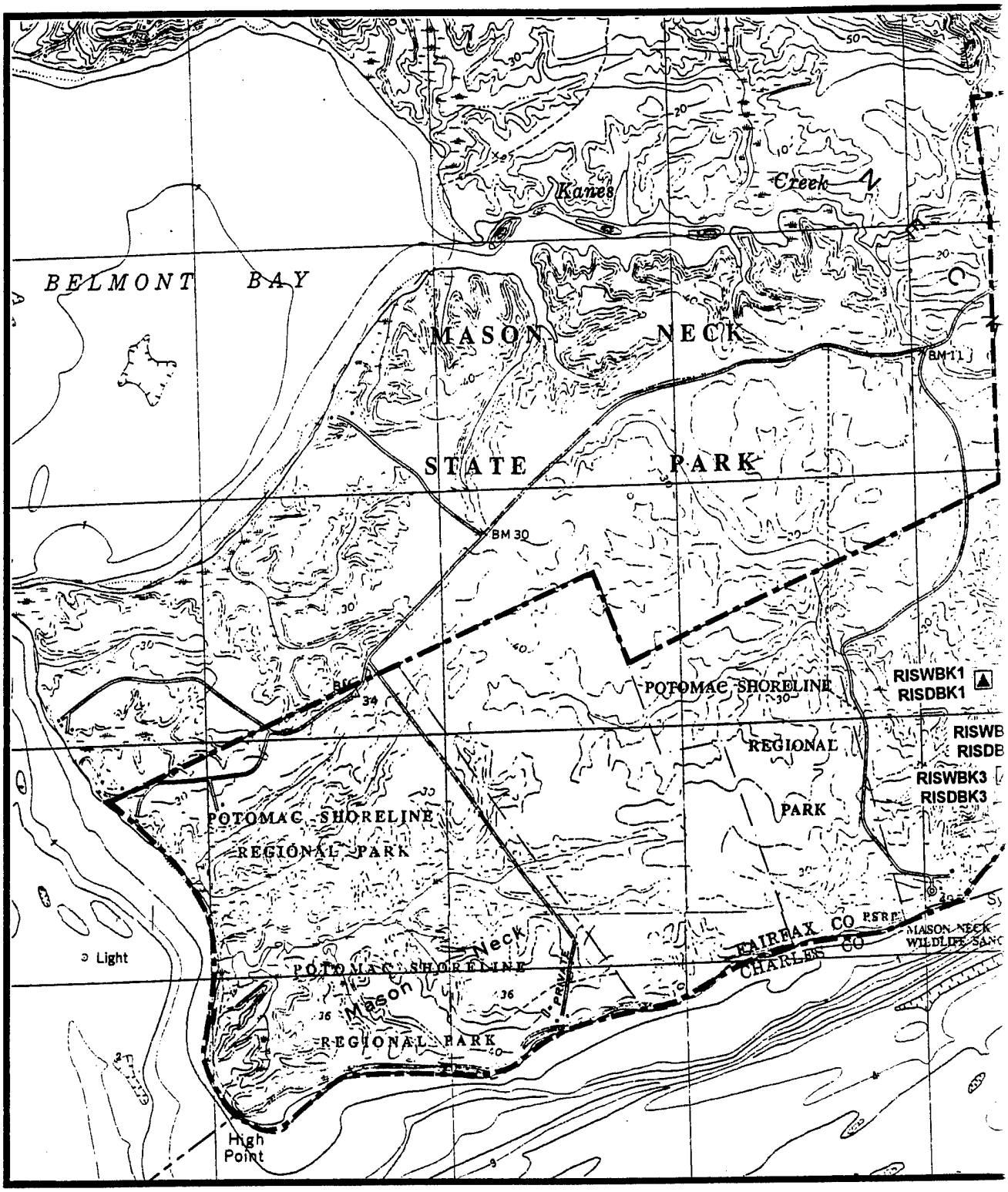
- BACKGROUND GROUNDWATER SAMPLE LOCATION
- BACKGROUND SURFACE SOIL SAMPLE LOCATION
- SWAMP

NOTE:
SUBSURFACE SOIL SAMPLES WERE COLLECTED FROM MW-52, MW-53, AND MW-54 SOIL BORINGS.

0 1000 2000
SCALE FEET

US ARMY ENVIRONMENTAL CENTER

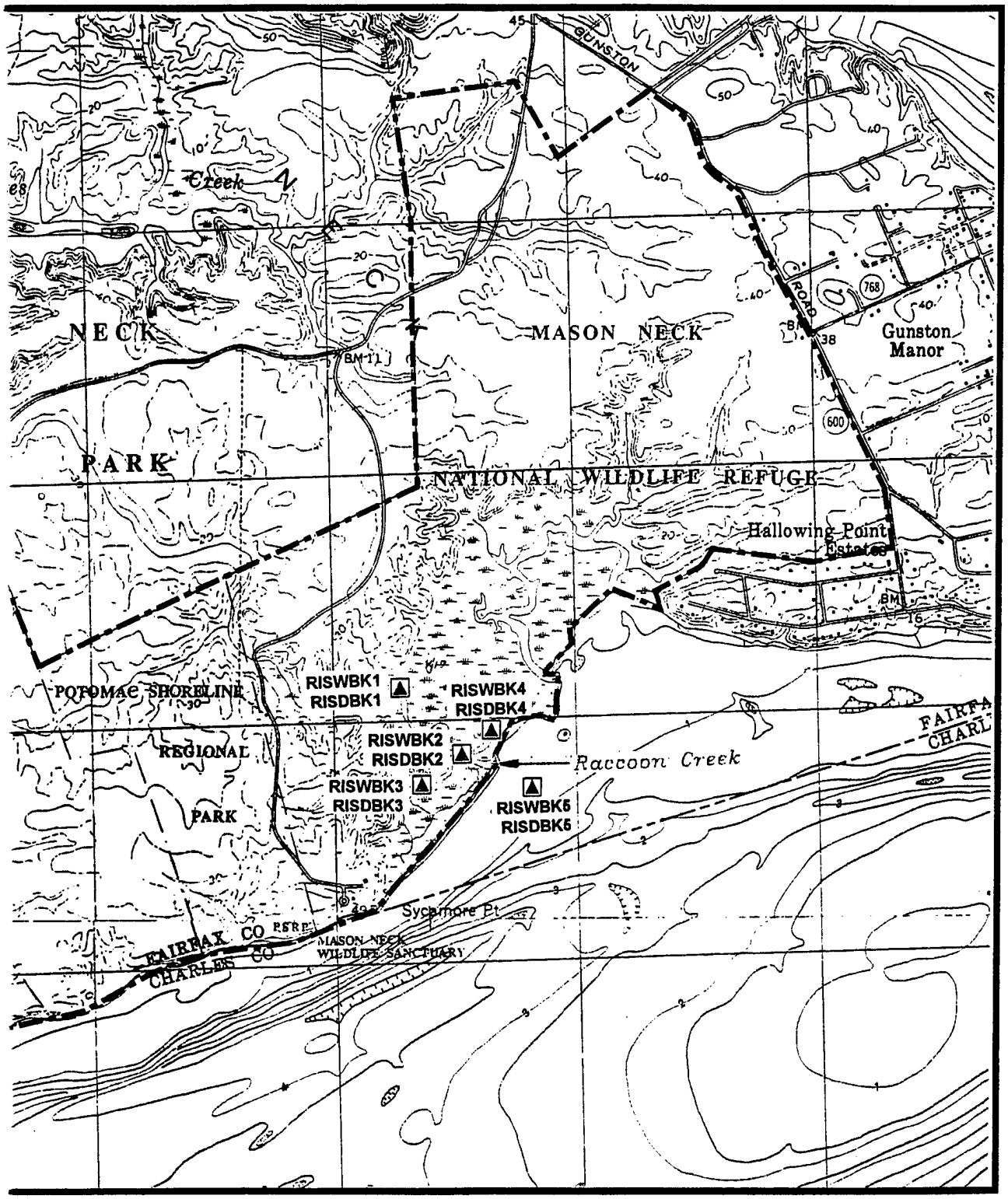
CONTRACT NO. DACA31-94-D-0064	FIGURE 2-23
	WOODBRIDGE RESEARCH FACILITY
ICF KAISER 1301 Continental Drive Suite 101 Abingdon, Maryland 21009 (410) 612-6350	**BACKGROUND SAMPLE LOCATIONS**
PREPARED CST	TASK NO: 66220
CHECKED PT	ICF DWG NO: STESMP6
DATE 08-21-97	

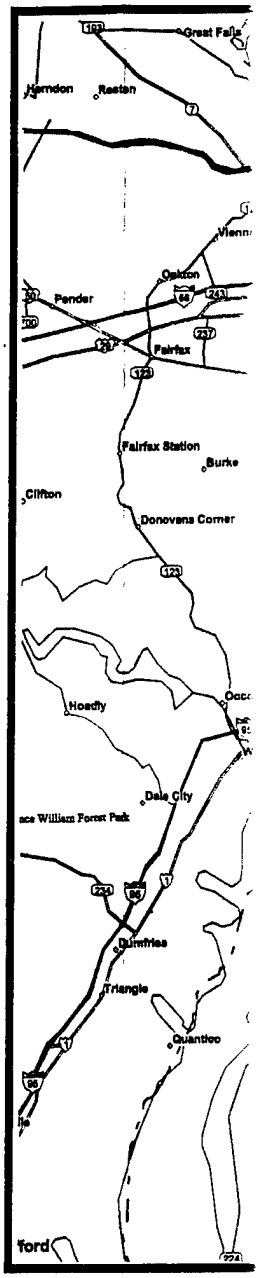


LEGEND:

▲ SURFACE WATER/SEDIMENT SAMPLE LOCATION

▬ ▪ ▬ ▪ ▬ REFUGE BOUNDARY





0 2000 4000
SCALE FEET

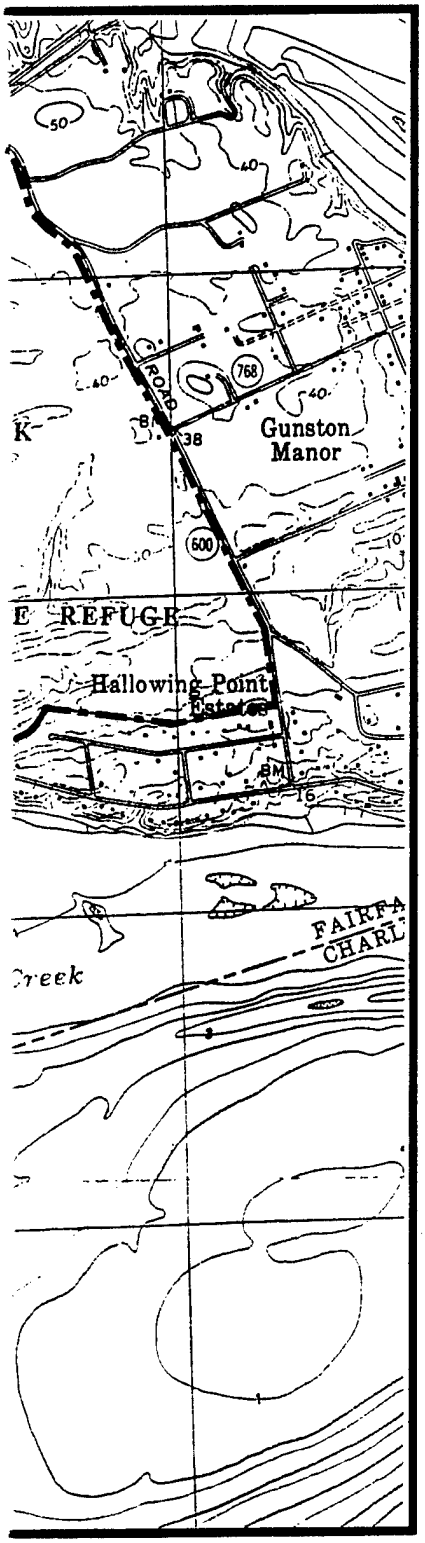
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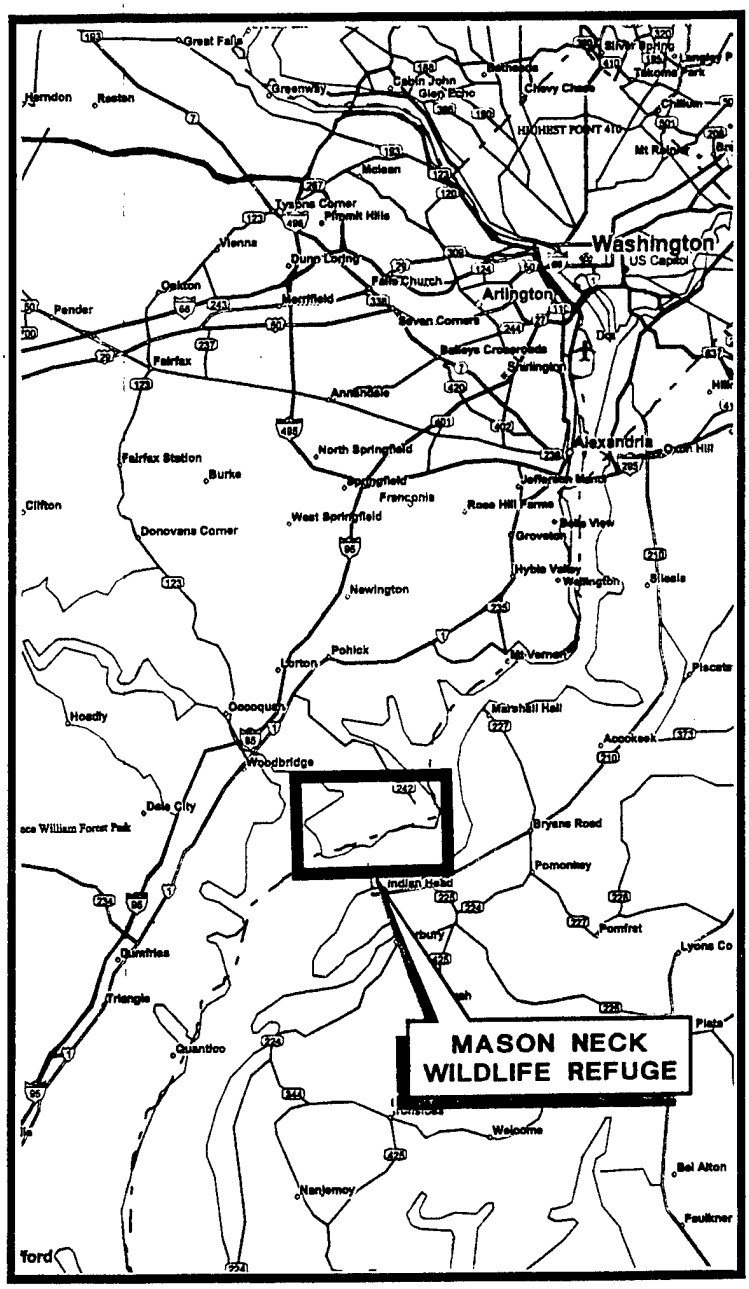
ENVIR

CONTRACT NO. DACA3

ICF KAISER

PREPARED	CST
CHECKED	PT
DATE	08-21-97





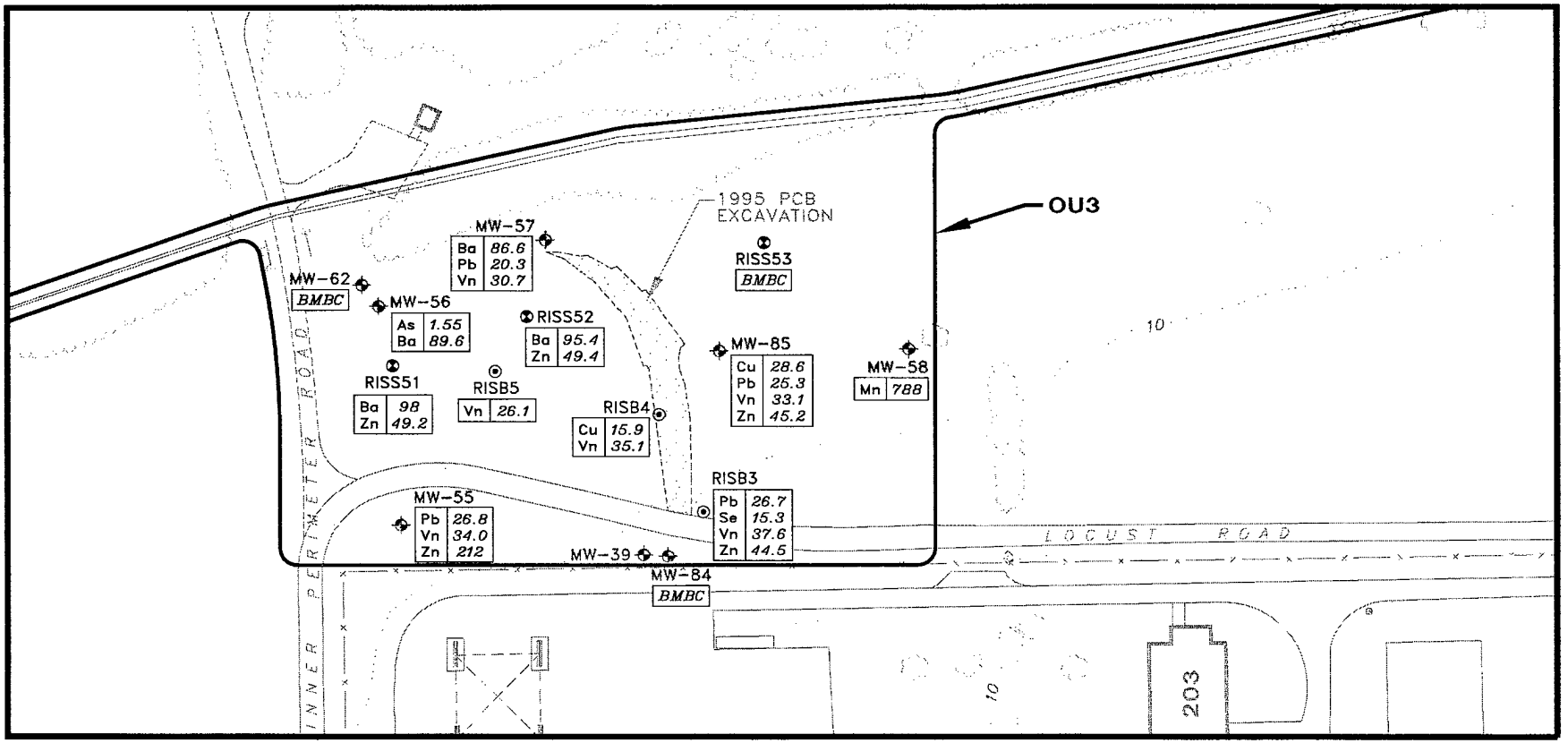
KEY PLAN

4000
FEET

N

US ARMY ENVIRONMENTAL CENTER

CONTRACT NO. DACA31-94-D-0064	FIGURE 2-24 WOODBRIDGE RESEARCH FACILITY
ICF KAISER 2113 Emmorton Park Drive Suite 100 Edgewood, Maryland 21040 (410) 612-6350	LOCATION OF BACKGROUND SURFACE WATER AND SEDIMENT SAMPLES FROM MASON NECK WILDLIFE REFUGE
PREPARED CST	TASK NO: 66220
CHECKED PT	ICF DWG NO: MNECKCP1
DATE 08-21-97	



LEGEND:

- MW-4 1995 RI MONITORING WELL LOCATION
- RISB4 1995 RI SOIL BORING LOCATION
- RISS-9 1995 RI SURFACE SOIL SAMPLE LOCATION
- MW-4 — LOCATION
- Pb 165, Zn 137 — CONCENTRATION IN µg/g — INORGANIC
- *BMBC* = BELOW MAXIMUM SITE BACKGROUND CONCENTRATION
- ROAD
- FENCE
- WATER
- TREE LINE
- 10 — TOPOGRAPHIC CONTOUR

NOTE:

NO SUBSURFACE ANALYTICAL DATA AVAILABLE FOR MW-39.

US ARMY ENVIRONMENTAL CENTER

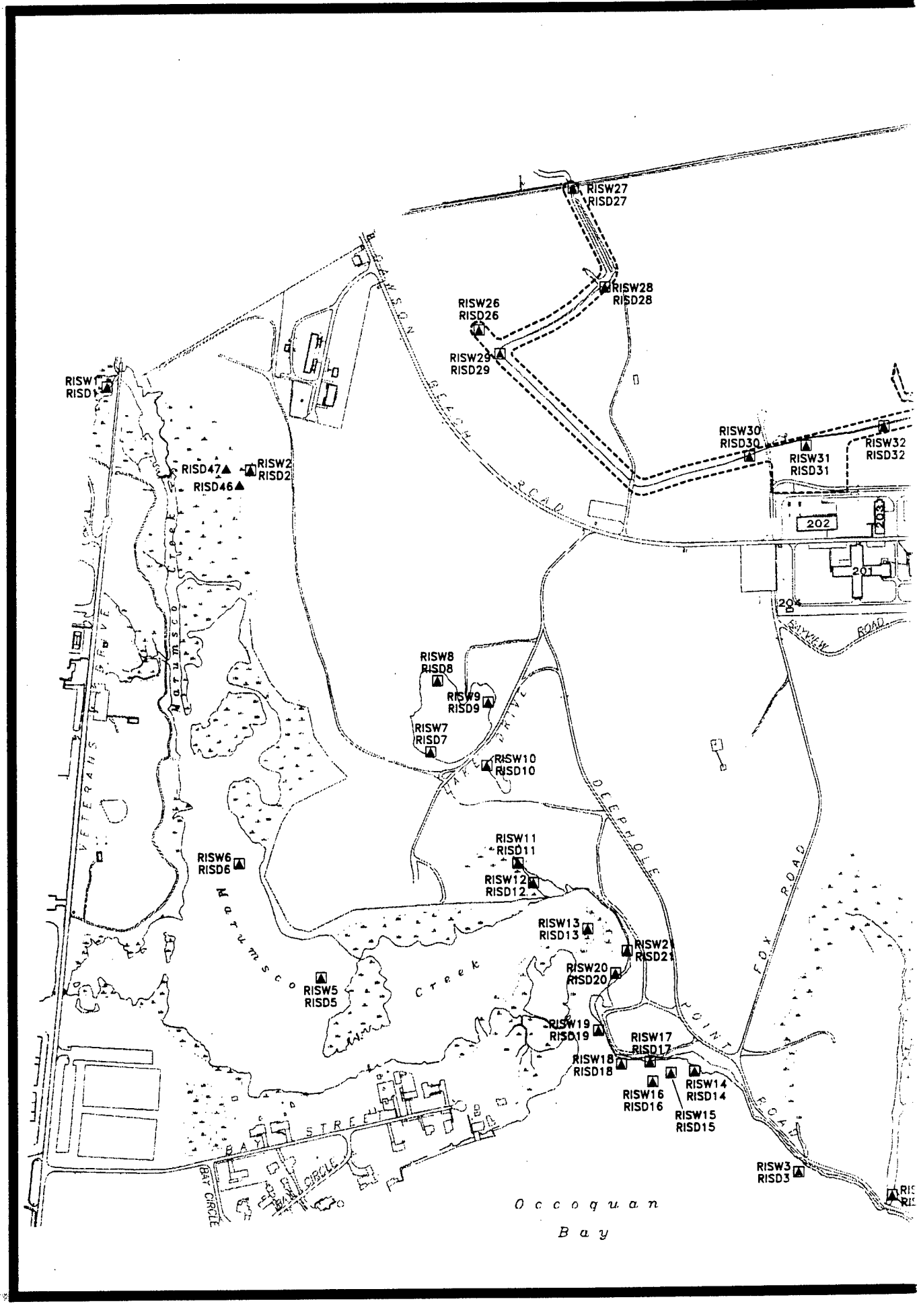
CONTRACT NO. DACA31-94-D-0064

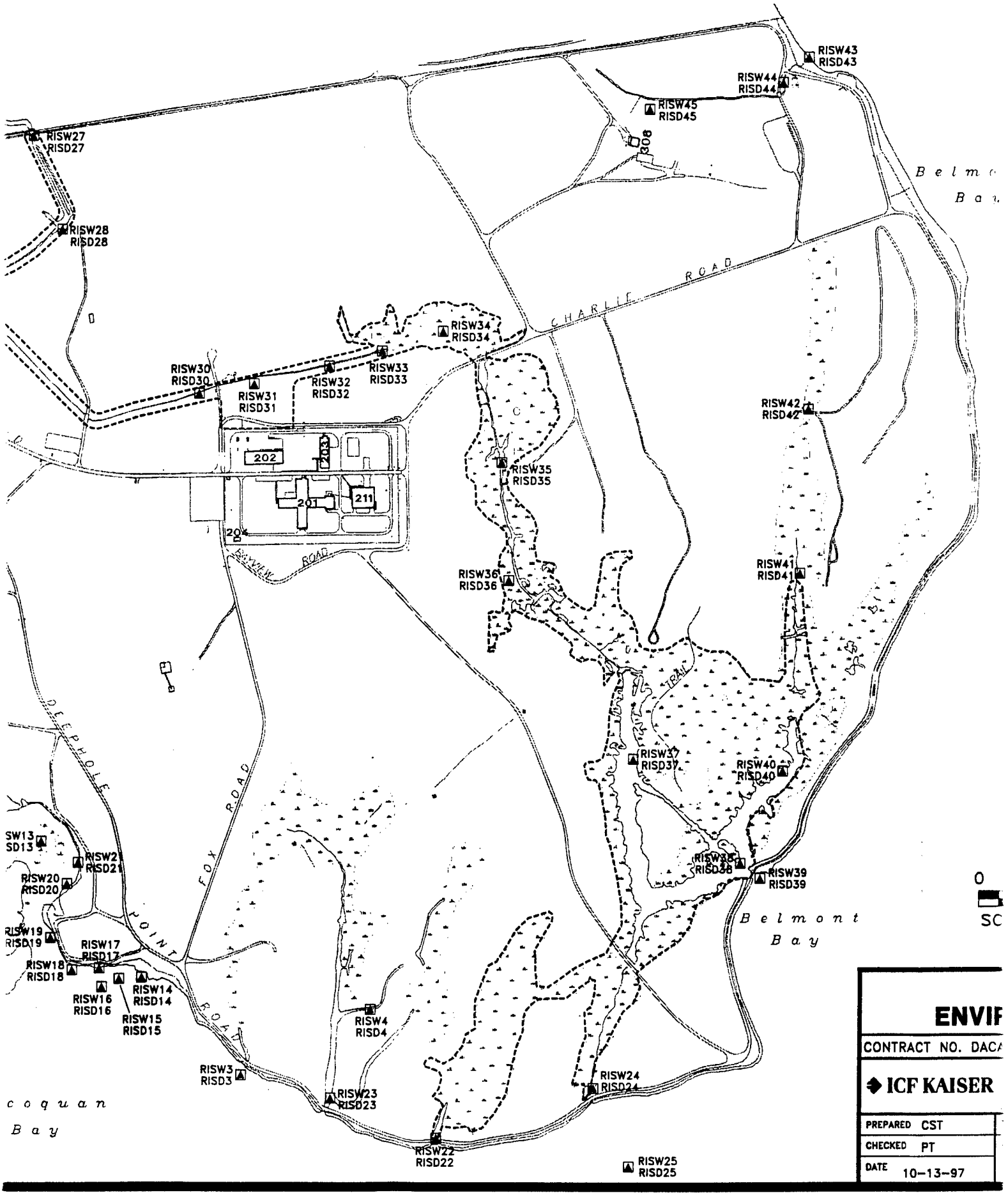
FIGURE 2-25
WOODBRIDGE RESEARCH FACILITY

ICF KAISER
2113 Emmorton Park Drive
Suite 100
Edgewood, Maryland 21040
(410) 612-6350

PREPARED CST	TASK NO: 66220
CHECKED PT	ICF DWG NO: FACRES6B
DATE 10-13-97	

OU3 SAMPLE LOCATIONS NORTH OF MAIN COMPOUND AREA


RISW27
RISD27
RISW28
RISD28
RISW26
RISD26
RISW29
RISD29
RISW30
RISD30
RISW31
RISD31
RISW32
RISD32
RISW1
RISD1
RISD47
RISW2
RISD2
RISD46
RISW8
RISD8
RISW9
RISD9
RISW7
RISD7
RISW10
RISD10
RISW11
RISD11
RISW6
RISD6
RISW12
RISD12
RISW13
RISD13
RISW21
RISD21
RISW20
RISD20
RISW5
RISD5
RISW19
RISD19
RISW17
RISD17
RISW18
RISD18
RISW16
RISD16
RISW14
RISD14
RISW15
RISD15
RISW3
RISD3
DAWSON BEACH ROAD
VETERANS DRIVE
Marumsco Creek
LAKE DRIVE
DEERHOLE
FOX POINT ROAD
BAY STREET
BAY CIRCLE
202
203
201
204
SKYVIEW ROAD
Occoquan
Bay

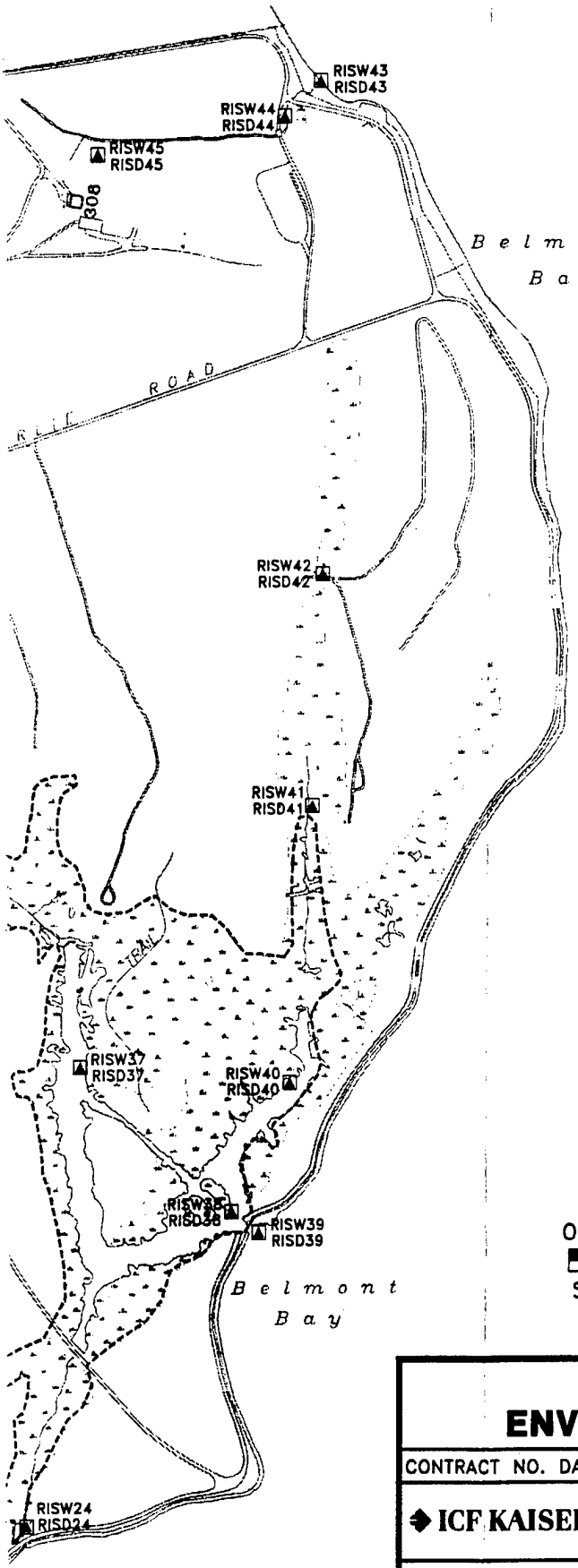


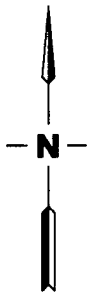
ENVIR

CONTRACT NO. DACA

◆ ICF KAISER

PREPARED	CST
CHECKED	PT
DATE	10-13-97





LEGEND:

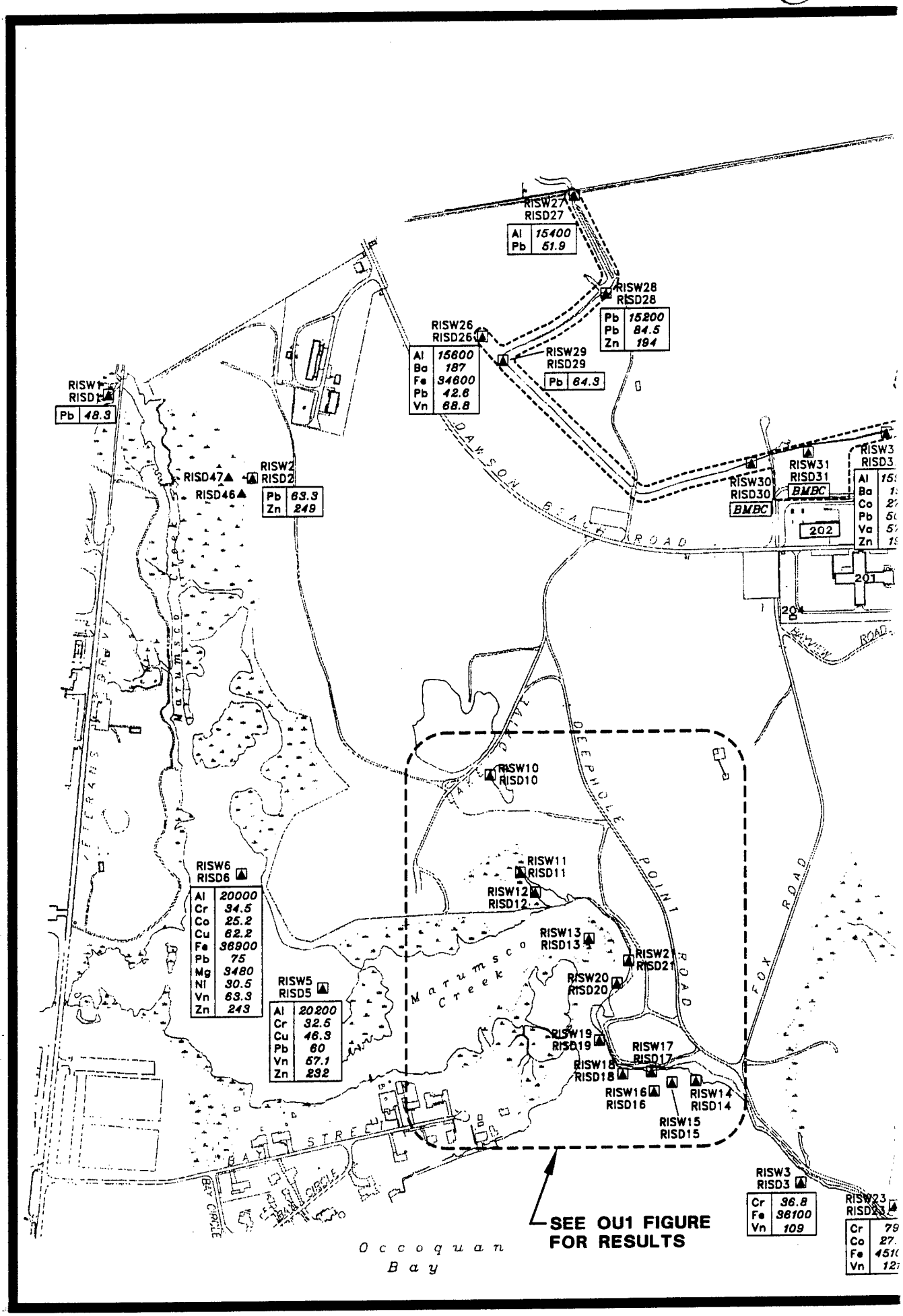
- ▲ RISD3 — SEDIMENT SAMPLE LOCATION
- RISW42 / RISD42 — SURFACE WATER/SEDIMENT SAMPLE LOCATION
- OU3 BOUNDARY
- ROAD
- FENCE
- WATER
- SWAMP

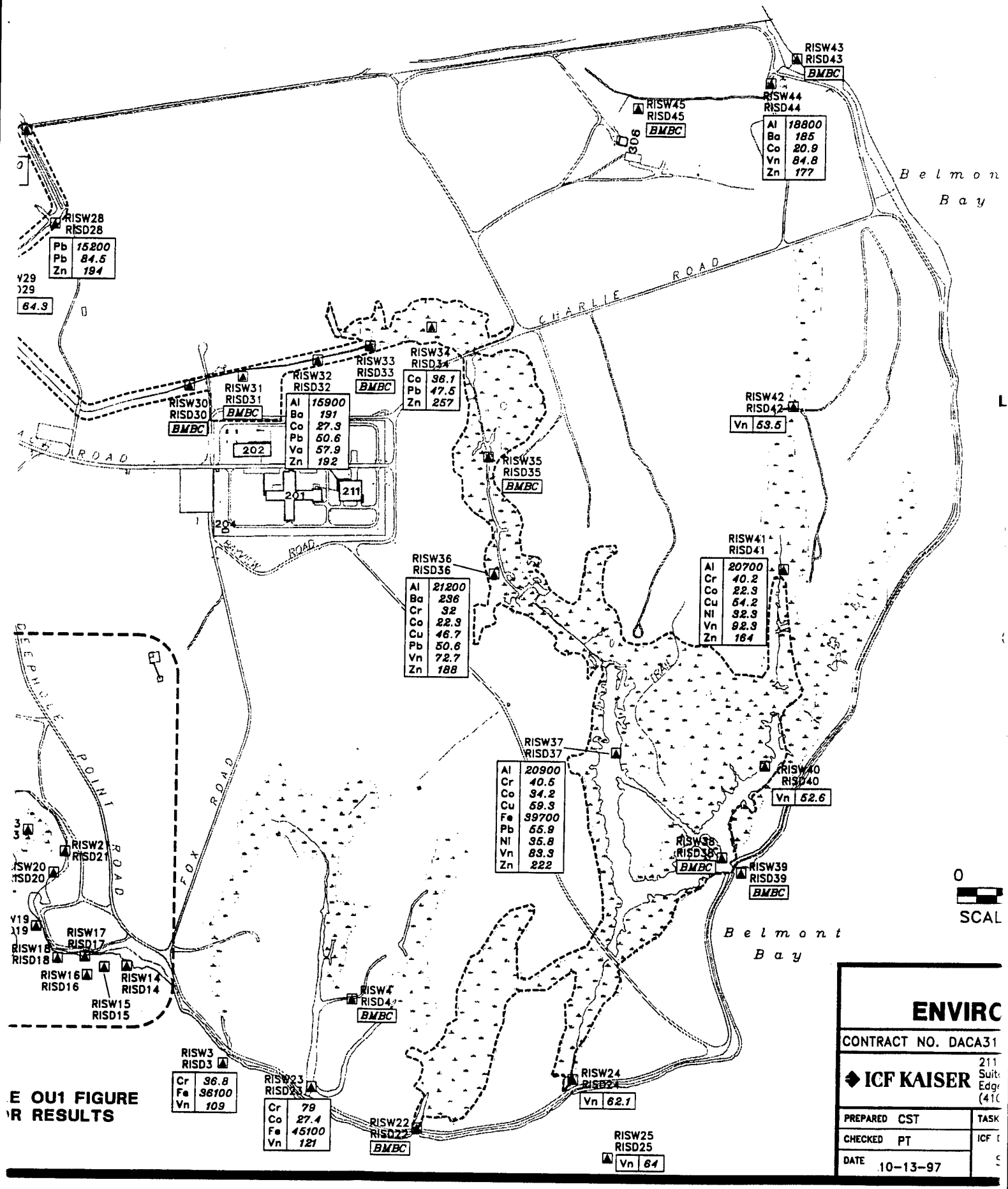
0 600 1200

SCALE FEET

US ARMY ENVIRONMENTAL CENTER

CONTRACT NO. DACA31-94-D-0064	FIGURE 2-26
ICF KAISER — 2113 Emmorton Park Drive, Suite 100, Edgewood, Maryland 21040, (410) 612-6350	WOODBRIDGE RESEARCH FACILITY
PREPARED CST / TASK NO: 66220	SURFACE WATER AND SEDIMENT SAMPLE LOCATIONS
CHECKED PT / ICF DWG NO:	
DATE 10-13-97 / STESMP7	


RISW27
RISD27
Al 15400
Pb 51.9
RISW28
RISD28
Pb 15200
Pb 84.5
Zn 194
RISW26
RISD26
Al 15600
Ba 187
Fe 34600
Pb 42.6
Vn 88.8
RISW29
RISD29
Pb 64.3
RISW1
RISD1
Pb 48.3
RISD47
RISD46
RISW2
RISD2
Pb 63.3
Zn 249
DAWSON BEACH ROAD
RISW30
RISD30
BMBC
RISW31
RISD31
BMBC
202
201
204
RISW3
RISD3
Al 15
Ba 1
Co 2
Pb 5
Va 5
Zn 1
RISW10
RISD10
RISW11
RISD11
RISW12
RISD12
RISW13
RISD13
RISW21
RISD21
RISW20
RISD20
RISW19
RISD19
RISW17
RISD17
RISW18
RISD18
RISW16
RISD16
RISW14
RISD14
RISW15
RISD15
RISW6
RISD6
Al 20000
Cr 34.5
Co 25.2
Cu 62.2
Fe 36900
Pb 75
Mg 3480
Ni 30.5
Vn 63.3
Zn 243
RISW5
RISD5
Al 20200
Cr 32.5
Cu 46.3
Pb 60
Vn 57.1
Zn 232
Matumsco Creek
DEEPHOLE POINT ROAD
FOX ROAD
BAY STREET
BAY CIRCLE
RISW3
RISD3
Cr 96.8
Fe 36100
Vn 109
RISW23
RISD23
Cr 79
Co 27
Fe 451
Vn 12
SEE OU1 FIGURE FOR RESULTS
Occoquan Bay



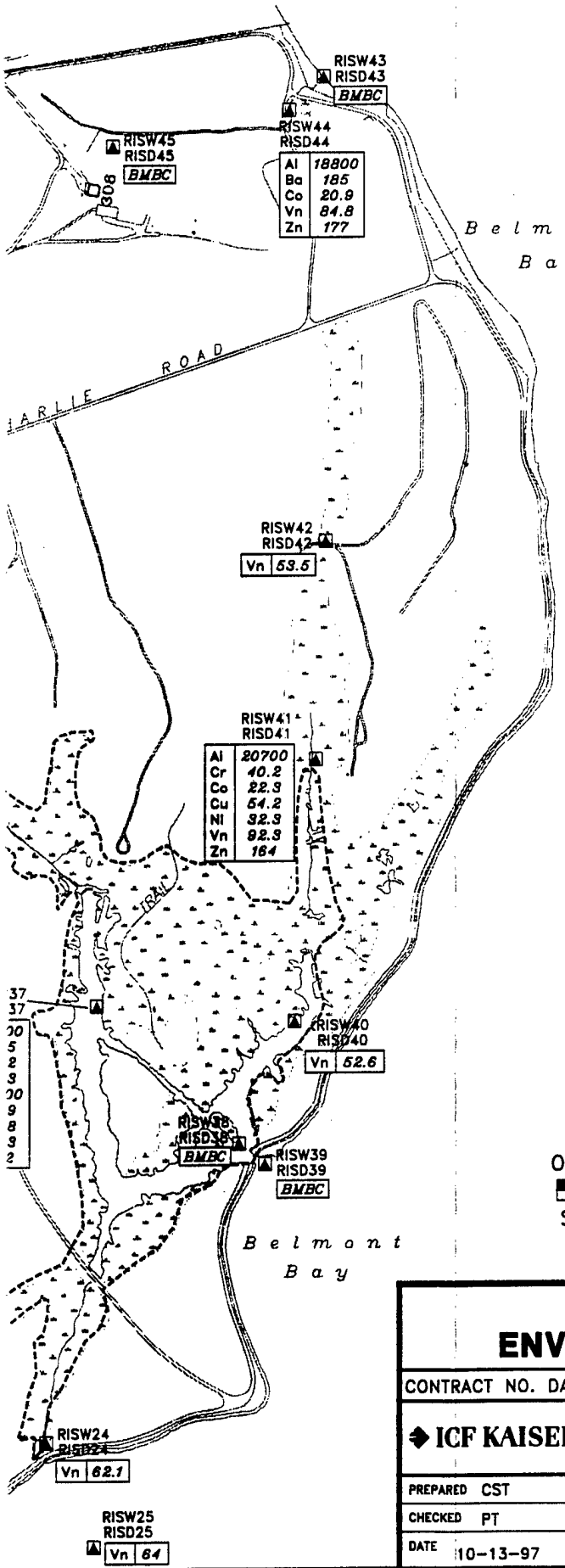
E OU1 FIGURE
R RESULTS

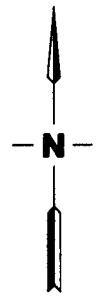
ENVIRC

CONTRACT NO. DACA31

ICF KAISER 211 Suit Edg (41(

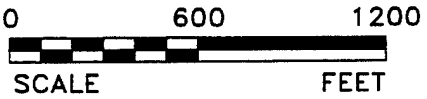
PREPARED CST	TASK
CHECKED PT	ICF
DATE 10-13-97	





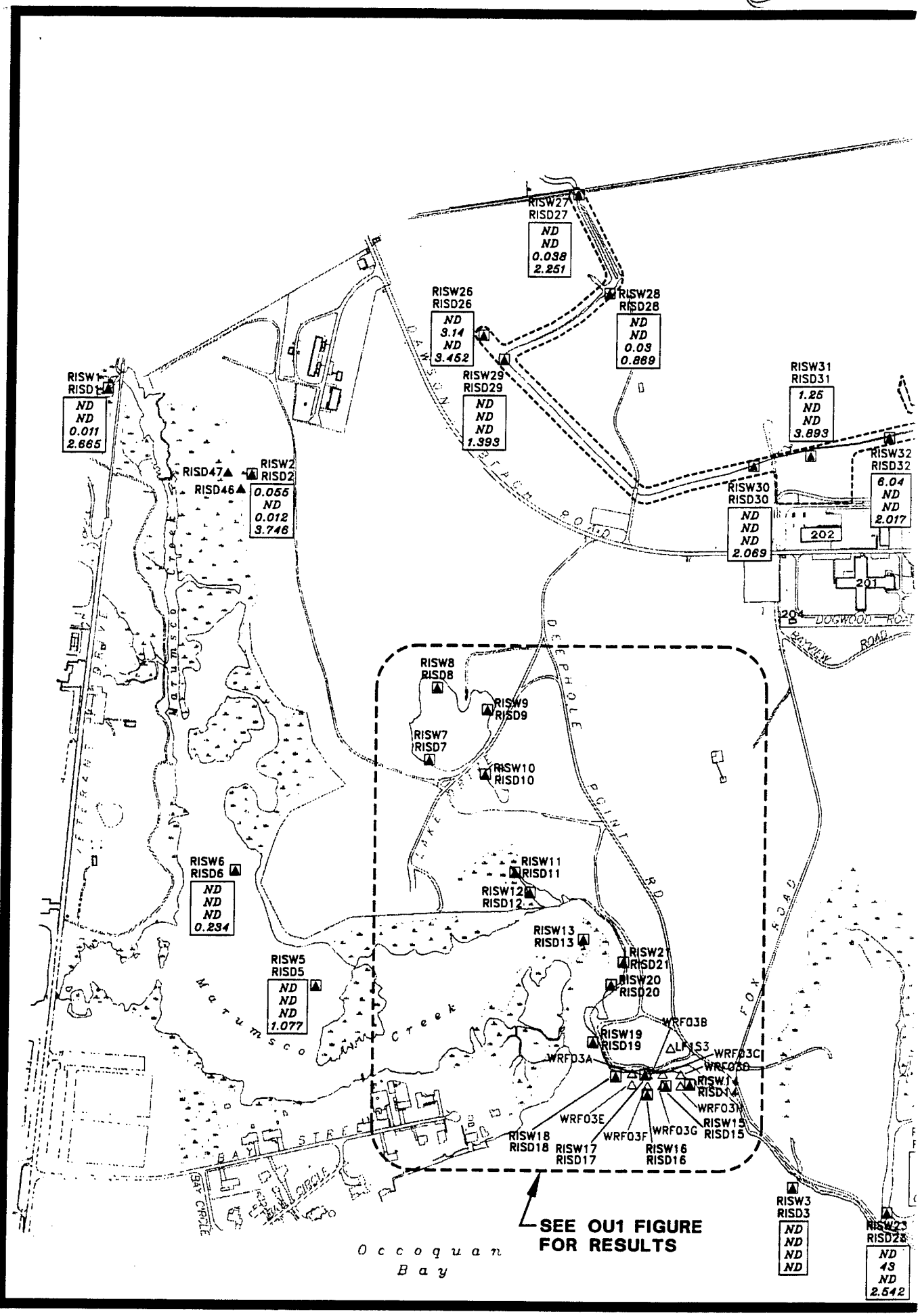
LEGEND:

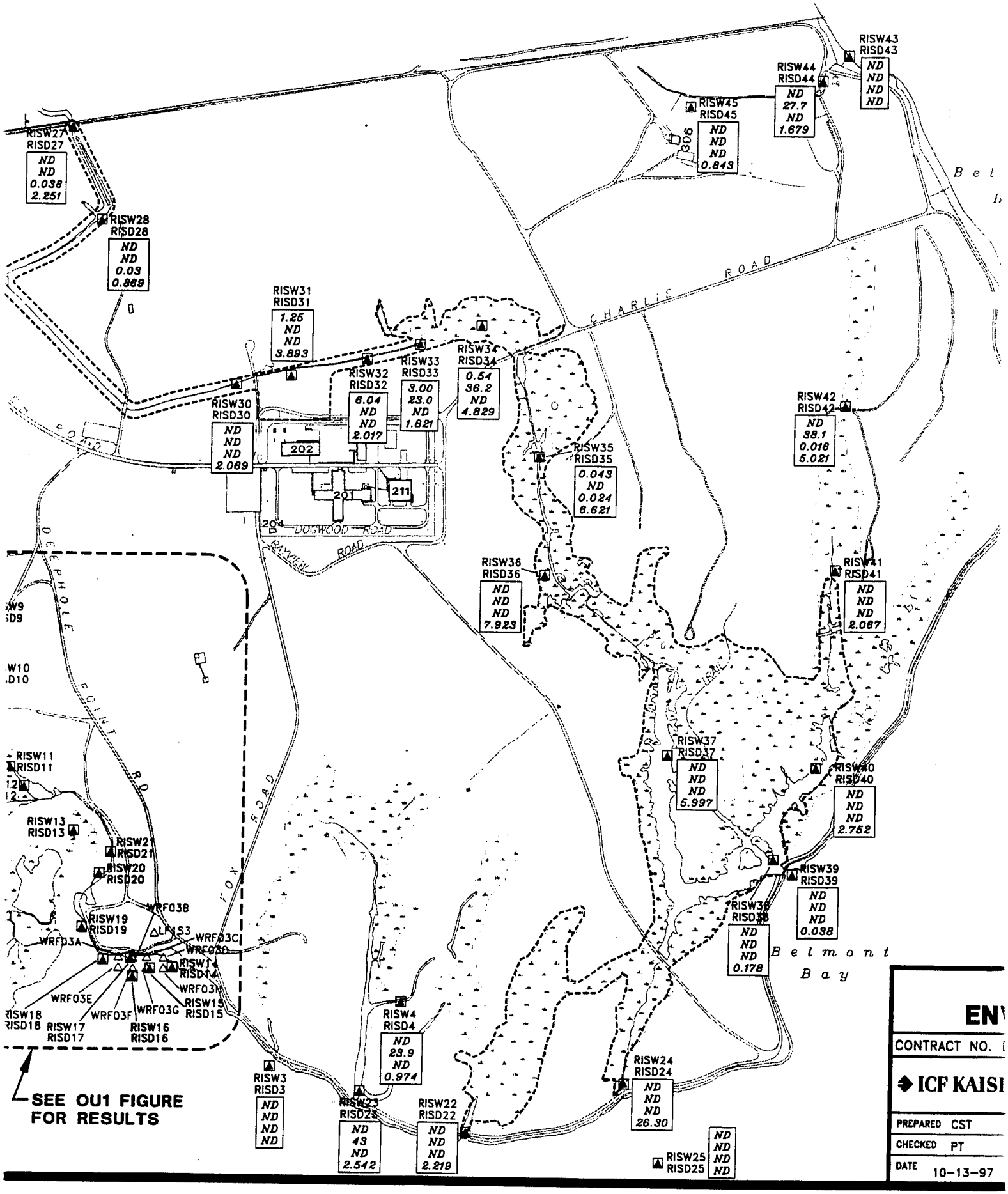
- ▲ RISD3 — SEDIMENT SAMPLE LOCATION
- RISW3 / RISE3 — SURFACE WATER/SEDIMENT SAMPLE LOCATION
- RISW3 / RISE3 — LOCATION
- Pb 165, Zn 137 — CONCENTRATION IN µg/g DRY
- INORGANIC
- *BMBC* = BELOW MAXIMUM SITE BACKGROUND CONCENTRATION
- OU3 BOUNDARY
- ROAD
- FENCE
- WATER
- SWAMP



US ARMY ENVIRONMENTAL CENTER

CONTRACT NO. DACA31-94-D-0064	FIGURE 2-27
ICF KAISER — 2113 Emmorton Park Drive, Suite 100, Edgewood, Maryland 21040, (410) 612-6350	WOODBRIDGE RESEARCH FACILITY
PREPARED CST / TASK NO: 66220	**INORGANICS DETECTED ABOVE BACKGROUND IN SITE-WIDE SEDIMENT SAMPLES**
CHECKED PT / ICF DWG NO:	
DATE 10-13-97 / STERES5	


RISW27
RISD27
ND
ND
0.038
2.251
RISW26
RISD26
ND
3.14
ND
9.462
RISW28
RISD28
ND
ND
0.03
0.869
RISW29
RISD29
ND
ND
ND
1.393
RISW31
RISD31
1.25
ND
ND
3.893
RISW32
RISD32
6.04
ND
ND
2.017
RISW30
RISD30
ND
ND
ND
2.069
RISW1
RISD1
ND
ND
0.011
2.665
RISD47
RISD46
RISW2
RISD2
0.056
ND
0.012
3.746
RISW8
RISD8
RISW9
RISD9
RISW7
RISD7
RISW10
RISD10
RISW6
RISD6
ND
ND
ND
0.234
RISW11
RISD11
RISW12
RISD12
RISW13
RISD13
RISW5
RISD5
ND
ND
ND
1.077
RISW21
RISD21
RISW20
RISD20
RISW19
RISD19
WRF03B
WRF03C
WRF03D
WRF03A
WRF03E
WRF03F
WRF03G
WRF03H
RISW18
RISD18
RISW17
RISD17
RISW16
RISD16
RISW15
RISD15
RISW3
RISD3
ND
ND
ND
ND
RISW23
RISD23
ND
43
ND
2.542
SEE OU1 FIGURE
FOR RESULTS
Occoquan
Bay
Marumsco Creek
DOGWOOD ROAD
FOX ROAD
DISPOSAL POINT RD
BAY STREET
202
201
204



EN

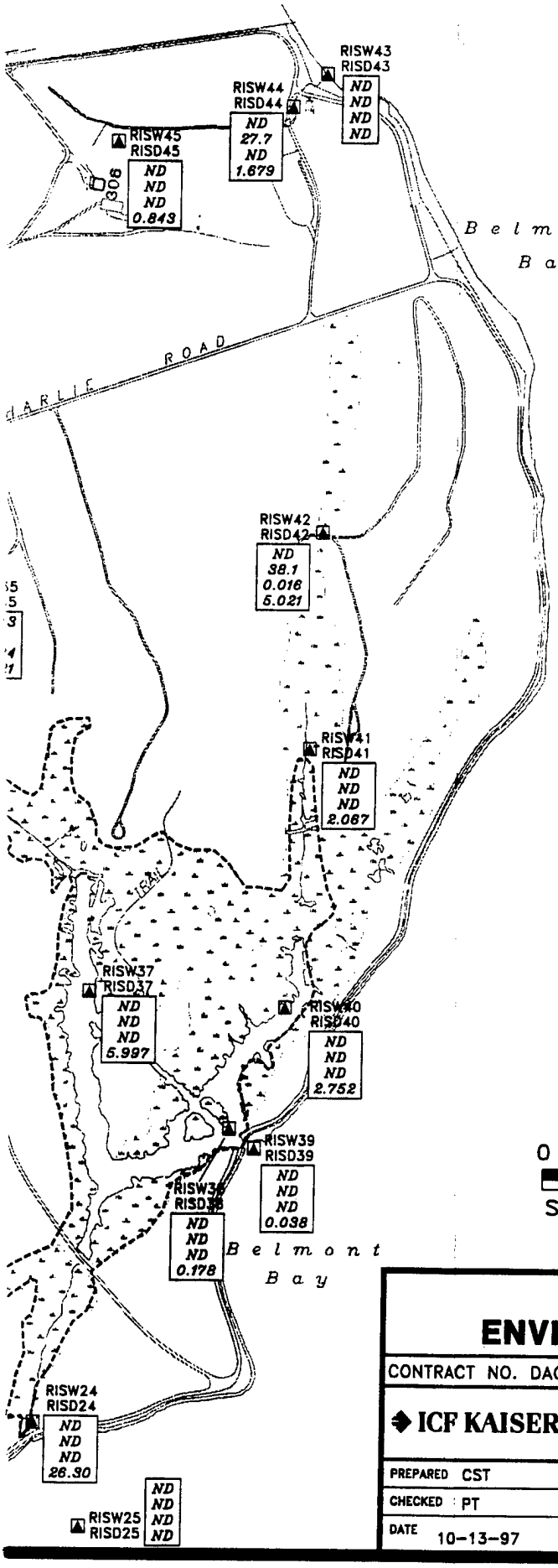
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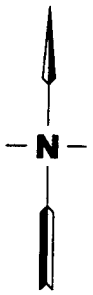
◆ ICF KAISI

PREPARED CST

CHECKED PT

DATE 10-13-97





LEGEND:

- ▲ RISD3 — SEDIMENT SAMPLE LOCATION
- RISW41 / RISD41 — SURFACE WATER/SEDIMENT SAMPLE LOCATION
- △ WRF03C — PRIOR SEDIMENT SAMPLE LOCATION
- RISW41 / RISD41 — LOCATION
- 0.04 — TOTAL PCBs IN µg/g DRY
- 6.03 — TOTAL TPH IN µg/g DRY
- 2.64 — TOTAL PESTICIDES IN µg/g DRY
- 1.24 — TOTAL PAHs IN µg/g DRY
- *ND* = NOT DETECTED
- OU3 BOUNDARY
- ROAD
- FENCE
- WATER
- SWAMP

0 600 1200
SCALE FEET

US ARMY ENVIRONMENTAL CENTER

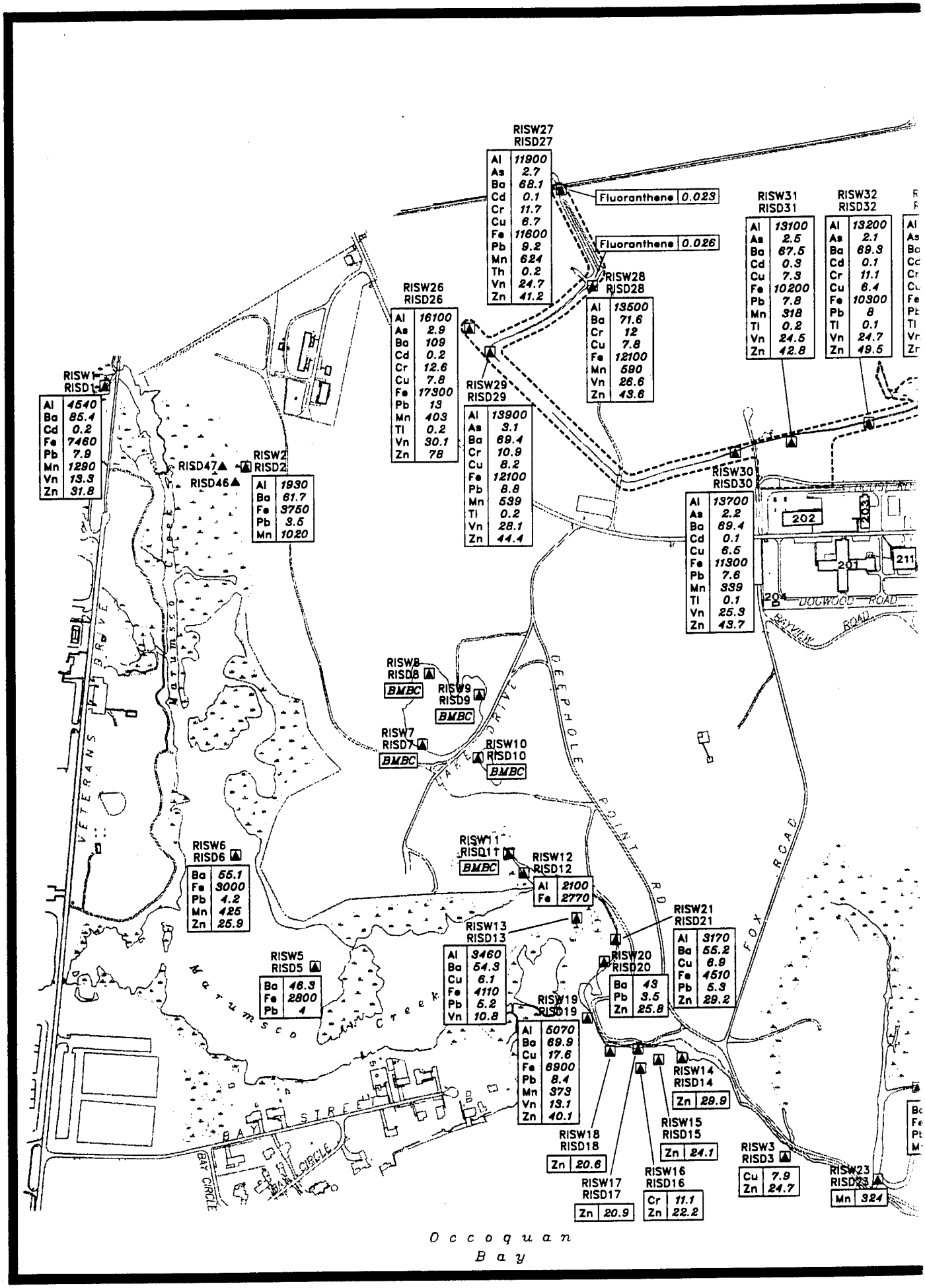
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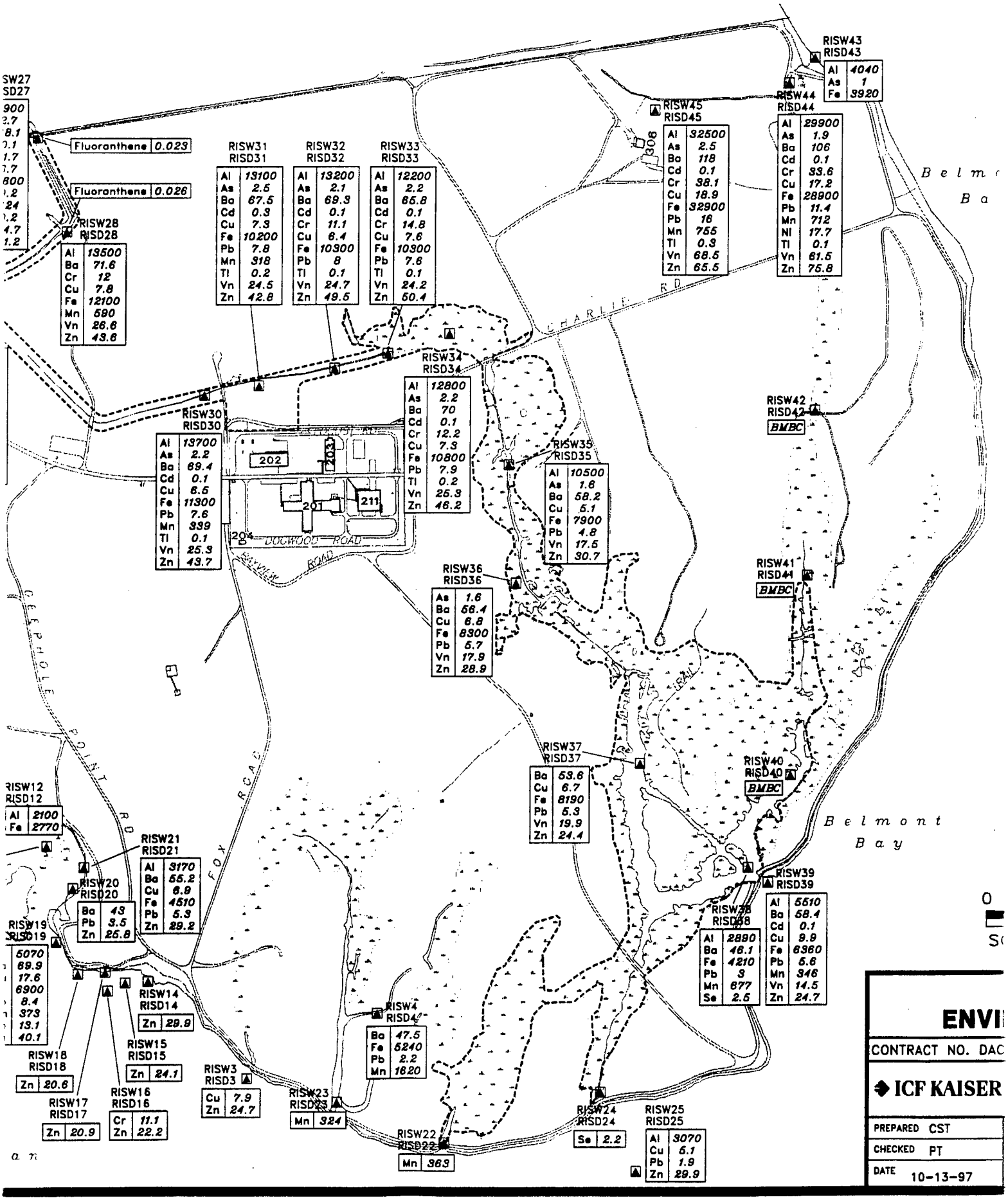
FIGURE 2-28
WOODBRIDGE RESEARCH FACILITY

ICF KAISER
2113 Emmorton Park Drive
Suite 100
Edgewood, Maryland 21040
(410) 612-6350

PREPARED CST
CHECKED PT
DATE 10-13-97
TASK NO: 66220
ICF DWG NO: STERES6

TOTAL PCBs, TOTAL TPH, TOTAL PESTICIDES, AND TOTAL PAHs DETECTED IN SITE-WIDE SEDIMENT SAMPLES


RISW27
RISD27
Al 11900
As 2.7
Ba 68.1
Cd 0.1
Cr 11.7
Cu 6.7
Fe 11600
Pb 9.2
Mn 624
Th 0.2
Vn 24.7
Zn 41.2
Fluoranthene 0.029
Fluoranthene 0.026
RISW31
RISD31
Al 13100
As 2.5
Ba 67.5
Cd 0.3
Cu 7.3
Fe 10200
Pb 7.8
Mn 318
Tl 0.2
Vn 24.5
Zn 42.8
RISW32
RISD32
Al 13200
As 2.1
Ba 69.3
Cd 0.1
Cr 11.1
Cu 6.4
Fe 10300
Pb 8
Tl 0.1
Vn 24.7
Zn 49.5
RISW28
RISD28
Al 13500
Ba 71.6
Cr 12
Cu 7.8
Fe 12100
Mn 590
Vn 26.6
Zn 43.6
RISW26
RISD26
Al 16100
As 2.9
Ba 109
Cd 0.2
Cr 12.6
Cu 7.8
Fe 17300
Pb 13
Mn 403
Tl 0.2
Vn 30.1
Zn 78
RISW29
RISD29
Al 13900
As 3.1
Ba 69.4
Cr 10.9
Cu 8.2
Fe 12100
Pb 8.8
Mn 539
Tl 0.2
Vn 28.1
Zn 44.4
RISW1
RISD1
Al 4540
Ba 85.4
Cd 0.2
Fe 7460
Pb 7.9
Mn 1290
Vn 13.3
Zn 31.8
RISD47
RISD46
RISW2
RISD2
Al 1930
Ba 61.7
Fe 3750
Pb 3.5
Mn 1020
RISW30
RISD30
Al 13700
As 2.2
Ba 69.4
Cd 0.1
Cu 6.5
Fe 11300
Pb 7.6
Mn 339
Tl 0.1
Vn 25.3
Zn 43.7
202
203
201
211
204
DOGWOOD ROAD
BAYVIEW ROAD
RISW8
RISD8
BMBC
RISW9
RISD9
BMBC
RISW7
RISD7
BMBC
RISW10
RISD10
BMBC
LAKE DRIVE
DEEPHOLE POINT RD
FOX ROAD
VETERANS BRIDGE
OSBOURNE
RISW6
RISD6
Ba 55.1
Fe 3000
Pb 4.2
Mn 425
Zn 25.9
RISW11
RISD11
BMBC
RISW12
RISD12
Al 2100
Fe 2770
RISW21
RISD21
Al 3170
Ba 55.2
Cu 6.8
Fe 4510
Pb 5.9
Zn 29.2
RISW13
RISD13
Al 3460
Ba 54.3
Cu 6.1
Fe 4110
Pb 5.2
Vn 10.8
RISW20
RISD20
Ba 43
Pb 3.5
Zn 25.8
RISW5
RISD5
Ba 48.3
Fe 2800
Pb 4
Neabsco Creek
RISW19
RISD19
Al 5070
Ba 69.9
Cu 17.6
Fe 6900
Pb 8.4
Mn 373
Vn 13.1
Zn 40.1
RISW14
RISD14
Zn 28.9
RISW15
RISD15
Zn 24.1
RISW18
RISD18
Zn 20.6
RISW16
RISD16
Cr 11.1
Zn 22.2
RISW17
RISD17
Zn 20.9
RISW3
RISD3
Cu 7.9
Zn 24.7
RISW23
RISD23
Mn 324
BAY STREET
BAY CIRCLE
Occoquan
Bay

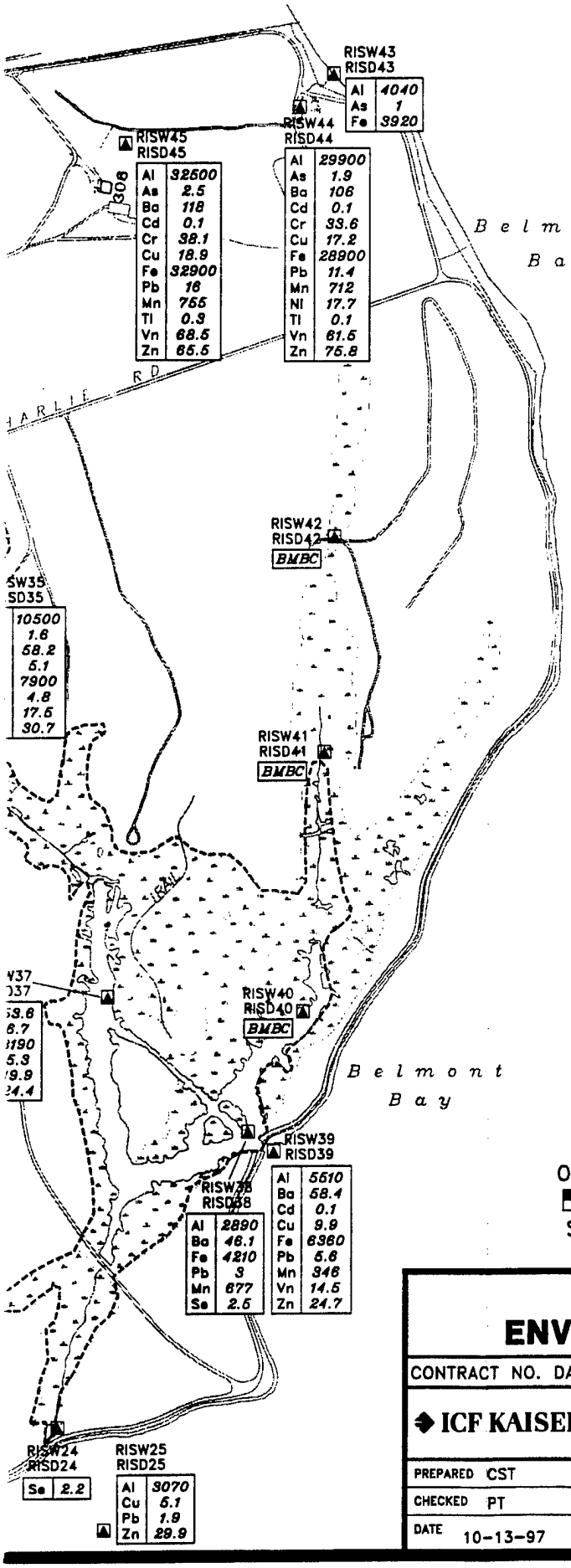


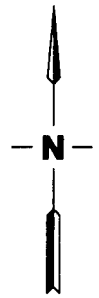
ENVI

CONTRACT NO. DAC

ICF KAISER

PREPARED	CST
CHECKED	PT
DATE	10-13-97





LEGEND:

- ▲ RISD3 — SEDIMENT SAMPLE LOCATION
- ▲ RISW42 / RISD42 — SURFACE WATER/SEDIMENT SAMPLE LOCATION
- RISW42 / RISD42 — LOCATION
- Pb 165, Zn 137 — CONCENTRATION IN µg/L
- INORGANIC
- *BMBC* = BELOW MAXIMUM SITE BACKGROUND CONCENTRATION
- OU3 BOUNDARY
- ROAD
- FENCE
- WATER
- SWAMP

NOTE:

NO PESTICIDES WERE DETECTED IN SURFACE WATERS AND PAHs WERE DETECTED IN TWO SAMPLES ONLY. RESULTS SHOWN IN RED.

0 600 1200

SCALE FEET

US ARMY ENVIRONMENTAL CENTER

CONTRACT NO. DACA31-94-D-0064

FIGURE 2-29

WOODBRIDGE RESEARCH FACILITY

ICF KAISER
2113 Emmorton Park Drive
Suite 100
Edgewood, Maryland 21040
(410) 612-6350

PREPARED CST

TASK NO: 66220

CHECKED PT

ICF DWG NO: STERES7

DATE 10-13-97

TOTAL PESTICIDES AND INORGANICS DETECTED ABOVE BACKGROUND IN SURFACE WATER

Table 2-1
Woodbridge Research Facility Monitoring Well Information

Well ID	Ground Surface Elevation	Screen Midpoint Elevation	Feet of Clay Above Screen	Field Groundwater Elevation	Stabilized Groundwater Elevation	Variance Between Field and Stabilized Groundwater Elevation	Number of Lithologies in Screen	Type of Screen Lithology	Local Aquifer Condition at Well Based on Boring Log Data and Stabilized Groundwater Elevation
MW-52	17.53	-1.47	14	0.53	3.11	2.58	3	CL/ML/SC/GP	confined/semi-confined
MW-53	33.91	4.11	2	13.91	4.88	-9.03	1	SP	unconfined/semi-confined
MW-54	14.44	2.14	7	-0.56	4.65	5.21	3	CL/SP/SC	confined/semi-confined
MW-55	5.27	-4.73	3	-1.23	5.21	6.44	3	CH/CL/SP	confined/semi-confined
MW-56	3.99	-13.01	10	-11.01	6.1	17.11	1	CL	confined/semi-confined
MW-57	4.04	-12.96	10	-10.96	4.47	15.43	2	SC/SP	confined/semi-confined
MW-58	5.84	-3.16	1	0.84	4.63	3.79	3	CL/SM/SW	confined/semi-confined
MW-59	22.81	-4.19	10	-2.19	1.66	3.85	1	SM	confined/semi-confined
MW-60	23.48	-15.52	30	-11.52	1.81	13.33	2	CH/SP	confined/semi-confined
MW-61	17.16	1.16	5	3.16	4.42	1.26	1	SP	unconfined/semi-confined
MW-62	4.14	-30.86	30	-30.86	5.44	36.3	2	CH/SP	confined/semi-confined
MW-63	34.12	-10.88	12	17.12	4.79	-12.33	3	GP/SP/CL	unconfined/semi-confined
MW-64	22.46	4.46	1	2.46	2.34	-0.12	5	CL/ML/CH/GM/SP	confined/semi-confined
MW-65	3.9	-15.1	14	-13.1	2.52	15.62	4	SC/CL/CH/GC	confined/semi-confined
MW-66	6.02	-4.98	0	0.02	2.35	2.33	4	SW/SM/CL/SC	unconfined/semi-confined
MW-67	7.43	-4.07	0	1.43	2.15	0.72	3	ML/CL/SM	unconfined/semi-confined
MW-68	12.16	0.16	5	2.16	4.23	2.07	1	SP	confined/semi-confined
MW-69	3.81	-20.19	0	-19.19	2.95	22.14	2	CL/SP	confined/semi-confined
MW-70	7.78	-2.22	5	1.78	3.02	1.24	2	SM/GP	confined/semi-confined
MW-71	8.92	-1.58	2	1.92	4.9	2.98	3	SC/CH/CL	confined/semi-confined
MW-72	6.77	-6.23	5	-3.23	3.95	7.18	3	SM/SC/CL	confined/semi-confined
MW-73	5.84	-12.66	10	-7.16	3.71	10.87	3	SW/CL/CH	confined/semi-confined
MW-74	5.44	-9.56	3	-7.56	2.06	9.62	4	CL/CH/SC/SP	confined/semi-confined
MW-75	6.14	-10.86	10	-8.86	1.76	10.62	2	SP/GP	confined/semi-confined
MW-76	2.8	-7.2	0	2.3	1.57	-0.73	4	SM/ML/SW/CL	unconfined/semi-confined
MW-77	6.49	-2.51	2	1.49	1.78	0.29	2	SM/SC	confined/semi-confined
MW-78	3.35	-6.65	0	-0.65	1.75	2.4	1	SP	unconfined/semi-confined
MW-79	5.56	-3.44	4	0.56	1.76	1.2	2	SM/SW	confined/semi-confined
MW-80	4.85	-6.15	4	0.85	1.78	0.93	2	SW/ML	confined/semi-confined
MW-81	8.22	-2.78	7	-1.78	3.96	5.74	2	SM/CL	confined/semi-confined
MW-82	8.39	-20.11	20	-16.61	2.95	19.56	2	SP/CL	confined/semi-confined
MW-83	8.89	-19.61	15	-21.11	2.97	24.08	3	CL/SM/GP	confined/semi-confined
MW-84	11.61	-20.39	10	-15.39	4.3	19.69	1	SW	confined/semi-confined
MW-85	4.63	-19.87	15	-16.37	5.6	21.97	2	CH/SC	confined/semi-confined
PZ-3	10.6	-6.4	8	0.6	9.78	9.18	2	CL/GP	confined/semi-confined
PZ-4	12.71	2.71	4	7.71	11.69	3.98	3	CL/GP/SW	confined/semi-confined
PZ-5	8.02	-2.38	3	2.02	4.13	2.11	4	ML/CL/SM/SP	confined/semi-confined
PZ-6	9.62	-17.38	25	-15.38	3.44	18.82	3	GP/SC/CH	confined/semi-confined
PZ-7	9.11	-3.89	0	-1.39	3.85	5.24	4	CL/SC/ML/CH	unconfined/semi-confined
PZ-8	3.43	-3.57	0	-0.57	2.87	3.44	4	CL/SP/SW/SM	unconfined/semi-confined
PZ-9	2.64	-8.36	2	-7.36	1.21	8.57	2	SW/SC	unconfined/semi-confined
PZ-10	3.47	-6.23	0	0.9	1.71	0.81	3	SW/SP/CL	unconfined/semi-confined
PZ-11	3.21	-11.79	10	-6.79	1.42	8.21	2	SW/GP	confined/semi-confined
PZ-12	16.53	1.53	10	5.53	6.99	1.46	3	ML/CH/GP	confined/semi-confined
PZ-13	7.15	-12.85	15	-8.85	2.89	11.74	2	SC/CH	confined/semi-confined

NOTES:

[1]Shaded areas represent greater than 5 foot variance between field observed water level and equilibrium (stabilized) water level in wells.
[2]Screen lithology codes consistent with ASTM standard D2488.

Table 2-2
Areas Requiring Environmental Evaluation
Woodbridge Research Facility

AREE NUMBER	DESCRIPTION	AREE NUMBER	DESCRIPTION
1	Former Dump No. 1	23b	Former 1,000 Gal. UST at Building 202
2	Former Dump No. 2	23c	Former 2,000 Gal. UST at Building 203
3	Former Dump No. 3	24a	Former 2,000 Gal. Diesel UST at Building 202
4	Former Dump No. 4	24b	Former 1,000 Gal. Gas UST at Building 202
5	Former Dump No. 5	24c	Former 10,000 Gal. Fuel Oil UST at Building 203
6A	Former Dump No. 6A	24d	Former 1,500 Gal. Fuel Oil UST Building 211
6B	Former Dump No. 6B	24f	Former 300 Gal. Diesel UST at Building 306
7	Former Pistol Range	25	Sewage Injection Areas
8	Underground Storage Tank Leaks/Spills at Building 202	26	Ethylene Glycol Area
9	Salt Contamination at Test Area	27	Buried Wire
10	Maintenance Shop (Building 202)	28	Radon
11	Building 202 Drainage Devices	29	VEPCO Transformer Spill
12	Drum Storage Area (Building 202)	30	Hydraulic Oil Spill
13	Acid Neutralization Tank (Building 211)	31	Low-Level Radioactive Material
14	Oil/Water Separator (Building 211)	32	Lead Paint
15	PCB Transformer	33	Bulldozer Fuel Spills
16	Asbestos	34	Hunter Qualification Target Range
17	Petroleum Spill Area (Building 202)	35	Former Antenna Field Sites
18	Flammable/Battery Storage (Building 204)	36	GVF Test Structure
19	Thermal Battery Storage	37	Creosote Pole Disposal Sites
20	Former Incinerator	38	NVCC Study Area
21	Former Storage Area (Building 211)	39	Debris Piles
22	Drainage Ditch	40	Former Water Tower
23a	Former 1,000 Gal. UST at Building 101	41	Old Homestead Site

Table 2-3
Inorganic Compounds Detected in Background Surface Soil Samples

Sample ID	Aluminum (µg/g)	Arsenic (µg/g)	Barium (µg/g)	Beryllium (µg/g)	Calcium (µg/g)	Chromium (µg/g)	Cobalt (µg/g)
RIBKSS1	14,600	3.85	ND	0.694	ND	26.7	6.46
RIBKSS1Dup	14,100	ND	ND	0.576	ND	24.2	6.32
RIBKSS2	6,550	ND	ND	0.364	486	9.72	12.7
RIBKSS3	8,600	ND	67	0.712	918	18.4	9.77
RIBKSS4	6,810	ND	ND	ND	764	14.5	6.83
RIBKSS5	10,900	ND	73.4	0.785	1020	22.8	12

Sample ID	Copper (µg/g)	Iron (µg/g)	Lead (µg/g)	Magnesium (µg/g)	Manganese (µg/g)
RIBKSS1	7.77	23,900	17.2	1,290	119
RIBKSS1Dup	7.11	22,200	15	1,260	104
RIBKSS2	4.83	10,200	ND	881	412
RIBKSS3	12.6	21,900	18	1,340	513
RIBKSS4	5.72	12,700	15.5	1,250	266
RIBKSS5	8.7	18,200	22.4	1,700	677

Sample ID	Nickel (µg/g)	Potassium (µg/g)	Selenium (µg/g)	Sodium (µg/g)	Vanadium (µg/g)	Zinc (µg/g)
RIBKSS1	7.42	567	ND	384	47	33.1
RIBKSS1Dup	7.59	527	ND	391	43.4	31.4
RIBKSS2	3.87	413	ND	380	20.6	14.8
RIBKSS3	8.17	546	14.2	467	47.1	33.5
RIBKSS4	5.21	358	ND	483	30.8	24.7
RIBKSS5	8.98	597	ND	487	43	40.4

Surface soil samples collected were from background locations were analyzed for TCL VOCs, SVOCs, pesticides/PCBs,PAHs, PCTs, TPH, and TAL metals.

– No value available.

ND Not detected.

Table 2-4
Organic Compounds Detected in Background Surface Soil Samples

Sample ID	Aldrin (µg/g)	Anthracene (µg/g)	Benzo(a) anthracene (µg/g)	Benzo(a)pyrene (µg/g)	Benzo(b) fluoranthene (µg/g)	Benzo (g,h,i) perylene (µg/g)
RIBKSS1	ND	ND	ND	ND	0.002	ND
RIBKSS1Dup	ND	ND	ND	ND	ND	ND
RIBKSS2	0.003	ND	0.003	0.002	0.005	ND
RIBKSS3	ND	0.027	0.005	0.006	0.01	0.011
RIBKSS4	ND	0.028	0.004	0.006	0.009	0.011
RIBKSS5	ND	0.015	0.005	0.008	0.009	0.011

Sample ID	Benzo(k) fluoranthene (µg/g)	Flouranthene (µg/g)	Indeno (1,2,3-cd) pyrene (µg/g)	Methylene chloride (µg/g)	Phenanthrene (µg/g)	Pyrene (µg/g)
RIBKSS1	0.001	0.006	0.003	ND	0.341	ND
RIBKSS1Dup	0.001	0.005	0.003	ND	0.347	ND
RIBKSS2	0.002	0.006	0.008	ND	0.042	0.009
RIBKSS3	0.005	0.018	0.009	ND	ND	0.017
RIBKSS4	0.004	0.01	0.01	ND	ND	0.019
RIBKSS5	0.005	0.012	0.008	0.02	ND	0.023

Surface soil samples collected from background locations were analyzed for TCL VOCs, SVOCs, pesticides/PCBs,PAHs, PCTs, TPH, and TAL metals.

ND Not detected.

Table 2-5
Inorganics and Organics Detected in Subsurface Soil Samples (0 to 2 ft bgs) Collected at Background Locations

Sample ID	Aluminum (µg/g)	Barium (µg/g)	Beryllium (µg/g)	Calcium (µg/g)	Chromium (µg/g)	Cobalt (µg/g)	Copper (µg/g)
MW-52	4,740	ND	0.3	149	9.42	2.47	7.41
MW-53	22,000	92.4	0.814	1,150	31.3	16.6	11.5
MW-54	14,300	72.3	0.79	822	26.8	14.5	8.75

Sample ID	Iron (µg/g)	Lead (µg/g)	Magnesium (µg/g)	Manganese (µg/g)	Nickel (µg/g)	Potassium (µg/g)	Selenium (µg/g)
MW-52	7,630	ND	676	27.5	2.83	148	ND
MW-53	28,100	16.7	2,610	875	11.9	936	ND
MW-54	26,000	17.7	1,780	775	9.00	623	13.0

Sample ID	Sodium (µg/g)	Vanadium (µg/g)	Zinc (µg/g)	Arsenic (µg/g)	Bis (2-ethylhexyl) phthalate (µg/g)
MW-52	439	19.9	15.2	--	ND
MW-53	404	58.9	43.9	3.24	0.18
MW-54	453	49.0	39.4	--	0.50

Subsurface soil samples (0 to 2 ft bgs) collected from Background Locations were analyzed for TCL VOCs, SVOCs, pesticides/PCBs, PCTs, TAL Metals.

ND Not detected.

-- No value available.

Table 2-6
Inorganics Detected in Subsurface Soil Samples (2 ft bgs to Water Table) Collected in Background Locations

Sample ID	Depth bgs (ft)	Aluminum (µg/g)	Barium (µg/g)	Beryllium (µg/g)	Calcium (µg/g)	Chromium (µg/g)
MW-52	10	5,710	54.6	0.504	800	17.5
	17	2,000	ND	ND	562	3.66
MW-52 Dup	10	6,180	93.0	0.938	911	19.9
MW-53	10	2,660	ND	ND	113	4.24
	30	2,790	ND	ND	148	6.21
MW-54	5	18,200	67.4	1.02	454	25.0
	10	7,090	ND	0.346	265	11.7

Sample ID	Depth bgs (ft)	Cobalt (µg/g)	Copper (µg/g)	Iron (µg/g)	Lead (µg/g)	Magnesium (µg/g)	Manganese (µg/g)
MW-52	10	11.1	14.7	11,300	ND	2,870	161
	17	7.70	3.96	6,100	ND	768	145
MW-52 Dup	10	6.71	19.1	8,750	11.0	3,280	75.9
MW-53	10	ND	1.52	4,050	ND	366	51.8
	30	ND	2.30	2,490	ND	405	32.8
MW-54	5	13.9	14.0	27,800	11.8	3,700	617
	10	4.56	5.54	9,170	ND	1,670	100

Sample ID	Depth bgs (ft)	Nickel (µg/g)	Potassium (µg/g)	Sodium (µg/g)	Vanadium (µg/g)	Zinc (µg/g)
MW-52	10	14.9	462	927	22.8	36.9
	17	4.40	135	600	10.2	14.5
MW-52 Dup	10	20.9	480	939	28.7	55.6
MW-53	10	ND	184	320	6.92	5.45
	30	ND	148	373	6.90	ND
MW-54	5	12.5	624	446	60.3	38.3
	10	5.41	351	361	20.3	17.6

Subsurface soil samples (2 ft bgs to water table) collected from background locations were analyzed for TCL VOCs, SVOCs, pesticides/PCBs, TAL metals, and PCTs.

ND Not detected.

Table 2-7
Inorganic Compounds Detected in Background Sediment Samples Collected from Mason Neck Wildlife Refuge

Sample ID	Aluminum (µg/g)	Arsenic (µg/g)	Antimony (µg/g)	Barium (µg/g)	Beryllium (µg/g)	Cadmium (µg/g)	Calcuim (µg/g)	Chromium (µg/g)	Cobalt (µg/g)
RISDBK1	14,300	ND	ND	175	1.26	ND	6,000	29.9	20.7
RISDBK2	13,100	ND	ND	ND	1.11	ND	4,760	26.0	16.1
RISDBK3	16,900	ND	ND	ND	1.38	ND	5,070	33.7	21.4
RISDBK3Dup	11,700	ND	ND	ND	1.06	ND	3,410	24.6	14.8
RISDBK4	15,200	ND	ND	ND	1.08	ND	5,990	30.1	18.0
RISDBK5	10,500	ND	ND	ND	0.989	ND	5,140	21.6	14.6

Sample ID	Copper (µg/g)	Iron (µg/g)	Lead (µg/g)	Magnesium (µg/g)	Manganese (µg/g)	Mercury (µg/g)	Nickel (µg/g)	Potassium (µg/g)	Selenium (µg/g)
RISDBK1	40.6	34,200	42.2	3,450	1,690	ND	30.0	1,850	ND
RISDBK2	33.3	30,000	30.6	2,810	1,470	ND	22.4	1,730	ND
RISDBK3	44.4	36,500	41.8	3,740	1,220	ND	30.3	2,090	ND
RISDBK3Dup	34.0	23,600	ND	2,740	603	ND	21.6	1,550	ND
RISDBK4	41.8	32,300	ND	3,470	1,220	ND	26.9	2,120	ND
RISDBK5	29.8	26,100	29	2,470	1,580	ND	19.3	1,450	ND

Sample ID	Silver (µg/g)	Sodium (µg/g)	Thallium (µg/g)	Vanadium (µg/g)	Zinc (µg/g)	Carbon(TOC)
RISDBK1	ND	1,130	ND	51.5	139	5.02
RISDBK2	ND	1,240	ND	41.6	133	6.94
RISDBK3	ND	1,440	ND	54.1	168	10.1
RISDBK3Dup	ND	1,200	ND	39.6	128	5.63
RISDBK4	ND	1,710	ND	52.5	157	7.69
RISDBK5	ND	932	ND	35.5	114	4.46

Sediment samples collected were analyzed for TCL VOCs, SVOCs, pesticides/PCBs, PCTs, TAL metals, PAHs, and TPH.

-- No value available.

ND Not detected.

Table 2-8
Organics Detected in Background Sediment Samples Collected from Mason Neck Wildlife Refuge

Sample ID	1-Methyl naphthalene (µg/g)	Acenaphthene (µg/g)	Anthracene (µg/g)	Benzo(a) anthracene (µg/g)	Benzo(a) pyrene (µg/g)	Benzo(b) fluoranthene (µg/g)	Benzo(g,h,i) perylene (µg/g)
RISDBK1	ND	ND	ND	0.021	0.029	0.061	0.053
RISDBK2	ND	0.919	0.145	0.031	0.048	ND	ND
RISDBK3	0.93	ND	0.173	0.034	0.053	ND	0.09
RISDBK3Dup	1.14	1.27	0.164	0.027	0.05	ND	0.07
RISDBK4	ND	ND	0.108	0.027	0.048	0.083	0.046
RISDBK5	0.498	ND	0.11	ND	0.028	0.05	ND

Sample ID	Benzo(k) fluoranthene (µg/g)	Dibenz(a,h) anthracene (µg/g)	Flour-anthene (µg/g)	Fluorene (µg/g)	Indeno (1,2,3-cd) pyrene (µg/g)	Methylene chloride (µg/g)	Naphthalene (µg/g)	Pyrene (µg/g)
RISDBK1	0.017	ND	0.055	ND	0.094	0.03	ND	0.053
RISDBK2	0.032	0.022	0.059	ND	0.112	ND	ND	0.085
RISDBK3	0.033	0.025	0.096	0.297	0.137	ND	ND	0.114
RISDBK3Dup	0.029	0.016	0.092	ND	0.084	ND	0.636	0.108
RISDBK4	0.028	ND	0.094	0.355	0.094	ND	ND	0.116
RISDBK5	0.07	29.8	0.013	0.086	0.225	0.061	ND	0.13

Sediment samples collected from background locations were analyzed for TCL VOCs, SVOCs, pesticides/PCBs PCTs, TAL metals, PAHs, and TPH.

ND Not detected.

Table 2-9
Inorganic Compounds Detected in Background Surface Water Samples Collected from Mason Neck Wildlife Refuge

Sample ID	Aluminum (µg/L)	Arsenic (µg/L)	Antimony (µg/L)	Barium (µg/L)	Beryllium (µg/L)	Cadmium (µg/L)	Calcuim (µg/L)	Chromium (µg/L)	Cobalt (µg/L)
RISWBK1	1,860	1.4	ND	41.8	ND	ND	18,800	ND	ND
RISWBK2	1,840	ND	ND	41.3	ND	ND	19,300	10.8	ND
RISWBK3	1,440	ND	ND	36.9	ND	ND	20,400	ND	ND
RISWBK3Dup	1,160	ND	ND	38.5	ND	ND	21,700	ND	ND
RISWBK4	1,230	ND	ND	40.4	ND	ND	22,200	ND	ND
RISWBK5	1,930	ND	ND	40.6	ND	ND	19,000	ND	ND

Sample ID	Copper (µg/L)	Iron (µg/L)	Lead (µg/L)	Magnesium (µg/L)	Manganese (µg/L)	Mercury (µg/L)	Nickel (µg/L)	Potassium (µg/L)	Selenium (µg/L)
RISWBK1	ND	2,460	1.6	6,120	236	ND	ND	3,350	ND
RISWBK2	ND	2,500	1.9	6,100	196	ND	ND	3,670	ND
RISWBK3	ND	1,810	1.3	6,350	159	ND	ND	3,490	ND
RISWBK3Dup	ND	2,000	1.3	6,880	226	ND	ND	2,990	ND
RISWBK4	ND	2,020	1.4	7,500	303	ND	ND	2,870	ND
RISWBK5	ND	2,510	1.9	5,970	176	ND	ND	3,300	ND

Sample ID	Silver (µg/L)	Sodium (µg/L)	Thallium (µg/L)	Vanadium (µg/L)	Zinc (µg/L)	Alkalinity	Hardness	Residue Suspended (TSS)
RISWBK1	ND	13,000	ND	ND	ND	40	76.6	54
RISWBK2	ND	12,900	ND	ND	ND	50	80	41
RISWBK3	ND	13,100	ND	ND	ND	55	84	39
RISWBK3Dup	ND	14,300	ND	ND	ND	59	85.2	37
RISWBK4	ND	16,500	ND	ND	ND	63	93.6	28
RISWBK5	ND	12,500	ND	ND	ND	50	81.6	68

Surface water samples were analyzed for TCL VOCs, SVOCs, pesticides/PCBs, PCTs, TAL metals, PAHs, and TPH.

ND Not detected.

-- No value available.

Table 2-10
Inorganics Detected In Background Groundwater Samples
Round 1 & 2

Sample ID	Aluminum (µg/L)	Arsenic (µg/L)	Barium (µg/L)	Cadmium (µg/L)	Calcium (µg/L)	Chromium (µg/L)	Cobalt (µg/L)
Round 1							
MW-52	94.8	ND	107	ND	9,680	ND	ND
MW-53	12,500	1.1	74.9	0.8	5,450	22.3	ND
MW-54	117	ND	ND	0.1	2,250	ND	ND
MW-63	635	1.6	30.8	ND	24,300	ND	ND
Round 2							
MW-52	234	ND	98	ND	8,090	ND	ND
MW-53	293	ND	51.1	ND	5,420	ND	ND
MW-54	144	ND	ND	0.3	2,400	ND	ND
MW-63	780	6.9	30.3	ND	42,800	ND	ND
MW-63 Dup	514	6.5	27.2	0.2	41,600	ND	ND

Sample ID	Copper (µg/L)	Iron (µg/L)	Lead (µg/L)	Magnesium (µg/L)	Manganese (µg/L)	Nickel (µg/L)	Potassium (µg/L)
Round 1							
MW-52	ND	159	ND	6,030	60.8	18.4	1,450
MW-53	8.9	9,620	6.3	6,830	354	ND	6,490
MW-54	ND	194	ND	1,810	47.2	ND	ND
MW-63	ND	433	ND	3,580	12.0	ND	14,000
Round 2							
MW-52	ND	455	ND	5,940	48.4	ND	1,360
MW-53	ND	179	ND	7,720	18.9	ND	8,190
MW-54	ND	196	ND	2,020	35.2	ND	744
MW-63	ND	532	ND	225	10.8	ND	20,900
MW-63 Dup	ND	209	1.2	157	ND	ND	20,300

Table 2-10 (Continued)
Inorganics Detected In Background Groundwater Samples
Round 1 & 2

Sample ID	Selenium (µg/L)	Sodium (µg/L)	Thallium (µg/L)	Vanadium (µg/L)	Zinc (µg/L)
Round 1					
MW-52	2.1	16,600	ND	ND	46.0
MW-53	4.2	5,110	0.1	21.2	23.0
MW-54	ND	5,610	ND	ND	ND
MW-63	2.7	41,300	ND	12.3	ND
Round 2					
MW-52	ND	23,600	ND	ND	20.3
MW-53	ND	6,850	ND	ND	ND
MW-54	ND	5,720	ND	ND	ND
MW-63	ND	44,300	ND	31.4	ND
MW-63 Dup	ND	42,700	ND	28.2	ND

Groundwater samples were analyzed for TCL VOCs, SVOCs, pesticides/PCBs, PCTs, TAL metals, PAHs, and TPH.

ND Not detected.

-- No value available.

Table 2-11
Organics Detected In Background Groundwater Samples
Round 1 & 2

Sample ID	1-Methyl naphthalene (µg/L)	2-Methyl naphthalenene (µg/L)	Acenaphthene (µg/L)	Acenaphthylene (µg/L)	Anthracene (µg/L)	BHC,B (µg/L)
Round 1						
MW-52	ND	ND	ND	ND	0.113	ND
MW-53	ND	ND	ND	ND	ND	ND
MW-54	ND	ND	ND	ND	ND	ND
MW-63	119	80.5	11.0	6.34	ND	ND
Round 2						
MW-52	ND	ND	ND	ND	ND	ND
MW-53	ND	ND	ND	ND	ND	ND
MW-54	ND	ND	ND	ND	ND	ND
MW-63	101	79.3	4.17	3.01	2.00	0.017
MW-63Dup	ND	78.8	8.27	ND	ND	ND

Sample ID	BHC,G (Lindane) (µg/L)	Dieldrin (µg/L)	Dimethylpthalate (µg/L)	Endosulfan, B (µg/L)	Endosulfan sulfate (µg/L)	Endrin (µg/L)
Round 1						
MW-52	ND	ND	ND	ND	0.146	ND
MW-53	ND	ND	ND	ND	ND	ND
MW-54	ND	ND	ND	ND	ND	ND
MW-63	ND	ND	ND	0.021	0.027	0.022
Round 2						
MW-52	ND	ND	ND	ND	0.138	ND
MW-53	ND	ND	ND	ND	ND	ND
MW-54	ND	ND	ND	ND	ND	ND
MW-63	0.098	0.026	ND	ND	0.019	ND
MW-63Dup	ND	0.018	3.90	ND	ND	ND

Table 2-11 (continued)
Organics Detected In Background Groundwater Samples
Round 1 & 2

Sample ID	Ethylbenzene (µg/L)	Fluoranthene (µg/L)	Flourene (µg/L)	Heptachlor (µg/L)	Naphthalene (µg/L)	Phenanthrene (µg/L)	Pyrene (µg/L)
Round 1							
MW-52	ND	ND	ND	ND	ND	ND	ND
MW-53	ND	ND	ND	ND	ND	ND	ND
MW-54	ND	ND	ND	ND	ND	ND	ND
MW-63	13	0.063	3.2	ND	30	8.69	0.158
Round 2							
MW-52	ND	ND	ND	ND	ND	ND	ND
MW-53	ND	ND	ND	ND	ND	ND	ND
MW-54	ND	ND	ND	ND	ND	ND	ND
MW-63	5.30	0.069	1.87	ND	18.0	6.43	0.162
MW-63Dup	5.20	0.069	2.01	0.011	15.2	6.35	0.137

Sample ID	Toluene (µg/L)	TPH, As Diesel (µg/L)	TPH, As Gas (µg/L)	Xylenes (µg/L)
Round 1				
MW-52	ND	ND	ND	ND
MW-53	ND	ND	ND	ND
MW-54	ND	ND	ND	ND
MW-63	5.2	900	740	54
Round 2				
MW-52	ND	ND	ND	ND
MW-53	ND	ND	ND	ND
MW-54	ND	ND	ND	ND
MW-63	2.30	1,140	558	32.0
MW-63Dup	2.10	1,130	538	31.0

Groundwater samples collected were analyzed for TCL VOCs, SVOCs, Pesticides/PCBs, TAL Metals, PAHs, and PCTs.

ND Not detected.

Table 2-12
Inorganics Detected in Surface Soil Samples Collected in AREEs 11 and 17 North of the Main Compound

Sample ID	Aluminum (µg/g)	Barium (µg/g)	Beryllium (µg/g)	Calcium (µg/g)	Chromium (µg/g)	Cobalt (µg/g)
Site Background	**14,350**	**92.4**	**0.814**	**1,150**	**31.3**	**16.6**
RBC	**7,800**	**550**	**0.15**	**--**	**39**	**470**
RISS-51	7,180	98.0	0.684	777	10.1	9.77
RISS-52	8,940	95.4	0.786	693	11.9	7.47
RISS-53	5,610	57.6	0.387	339	8.74	4.94

Sample ID	Copper (µg/g)	Iron (µg/g)	Lead (µg/g)	Magnesium (µg/g)	Manganese (µg/g)	Nickel (µg/g)
Site Background	**12.6**	**28,100**	**22.4**	**2,610**	**875**	**11.9**
RBC	**310**	**2,500**	**400**	**--**	**39**	**160**
RISS-51	10.2	12,400	15.8	894	756	5.51
RISS-52	8.10	12,700	15.5	1,140	531	6.67
RISS-53	7.88	6,680	15.6	591	438	3.83

Sample ID	Potassium (µg/g)	Sodium (µg/g)	Vanadium (µg/g)	Zinc (µg/g)
Site Background	**936**	**487**	**58.9**	**43.9**
RBC	**--**	**--**	**55**	**2,300**
RISS-51	309	450	26.1	49.2
RISS-52	359	394	30.4	49.4
RISS-53	257	426	20.0	36.0

-- No value available.

ND Not detected.

RBC USEPA Region III residential risk-based concentration (RBC) values.

Table 2-12 (Continued)
Organics Detected in Surface Soil Samples Collected in AREEs 11 and 17
North of the Main Compound

Sample ID	1-Methyl-naphthalene (µg/g)	Anthracene (µg/g)	Benzo(a)-anthracene (µg/g)	Benzo(a)-pyrene (µg/g)	Benzo(b)-fluoranthene (µg/g)	Benzo(g,h,i)-perylene (µg/g)
RBC	**230[a]**	**2,300**	**0.88**	**0.088**	**0.88**	**230[a]**
RISS-51	11.2	0.068	0.008	0.012	0.04	0.024
RISS-52	ND	0.014	0.002	0.007	0.014	0.014
RISS-53	ND	ND	0.004	0.006	0.017	0.017

Sample ID	Benzo(k)-fluoranthene (µg/g)	Chrysene (µg/g)	Fluoranthene (µg/g)	Indeno(1,2,3-cd) pyrene (µg/g)	PCB-1260 (µg/g)	Pyrene (µg/g)
RBC	**8.8**	**88**	**310**	**0.88**	**0.083[b]**	**230**
RISS-51	0.021	0.052	0.068	0.022	0.04	0.041
RISS-52	0.006	ND	0.013	0.023	0.123	0.020
RISS-53	0.008	0.014	0.024	0.024	0.149	0.033

[a] The RBC for pyrene was used as a surrogate for noncarcinogenic polycyclic aromatic hydrocarbons (PAHs) lacking RBCs.

[b] Value is for carcinogenic PCBs.

ND Not detected.

RBC USEPA Region III residential risk-based concentration (RBC) values.

Table 2-12 (Continued)
Inorganics Detected in Subsurface Soil Samples (0 to 2 ft bgs)
Collected in AREEs 11 and 17 North of the Main Compound

Sample ID	Aluminum (µg/g)	Arsenic (µg/g)	Barium (µg/g)	Beryllium (µg/g)	Calcium (µg/g)	Chromium (µg/g)
Site Background	**18,200**	**--**	**73.8**	**1.02**	**454**	**25.0**
RBC	**7,800**	**0.43**	**550**	**0.15**	**--**	**39**
MW-55	10,600	ND	57.0	0.50	545	16.4
MW-56	9,000	1.55	89.6	0.67	733	12.1
MW-57	7,300	ND	86.6	0.98	674	11.4
MW-58	8,980	ND	62.8	0.55	427	13.7
MW-85	8,080	ND	52.7	0.471	1,440	14.5
RISB-3	10,900	1.90	48.1	0.63	851	20.2
RISB-4	8,480	ND	ND	0.29	973	15.9
RISB-5	8,220	ND	64.5	0.41	370	11.5

Sample ID	Cobalt (µg/g)	Copper (µg/g)	Iron (µg/g)	Lead (µg/g)	Magnesium (µg/g)	Manganese (µg/g)
Site Background	**13.9**	**16.9**	**27,800**	**11.8**	**3,700**	**617**
RBC	**470**	**310**	**2,500**	**400**	**--**	**180**
MW-55	5.70	10.6	14,800	26.8	955	312
MW-56	10.9	6.14	13,200	11.3	997	540
MW-57	7.10	8.07	12,700	20.3	935	300
MW-58	8.85	8.34	11,100	ND	1,090	788
MW-85	7.45	28.6	14,300	25.3	1,620	346
RISB-3	10.60	9.73	16,500	26.7	1,460	416
RISB-4	3.42	15.9	12,400	ND	1,240	115
RISB-5	4.54	6.34	7,640	11.3	721	180

Table 2-12 (Continued)
Inorganics Detected in Subsurface Soil Samples (0 to 2 ft bgs)
Collected in AREEs 11 and 17 North of the Main Compound

Sample ID	Nickel (µg/g)	Potassium (µg/g)	Selenium (µg/g)	Sodium (µg/g)	Vanadium (µg/g)	Zinc (µg/g)
Site Background	**17.9**	**624**	**--**	**933**	**25.8**	**46.3**
RBC	**160**	**--**	**39**	**--**	**55**	**2,300**
MW-55	5.66	455	ND	380	34.0	212
MW-56	6.86	911	ND	349	25.4	29.5
MW-57	5.89	339	ND	510	30.7	26.8
MW-58	6.18	346	ND	261	24.3	25.6
MW-85	7.69	326	ND	554	33.1	45.2
RISB-3	8.04	476	15.3	458	37.6	44.5
RISB-4	6.07	389	ND	457	35.1	18.1
RISB-5	4.53	341	ND	344	26.1	39.4

-- No value available.

ND Not detected.

RBC USEPA Region III residential risk-based concentration (RBC) values.

Table 2-12 (Continued)
Organics Detected in Subsurface Soil Samples (0 to 2 ft bgs)
Collected in AREEs 11 and 17 North of the Main Compound

Sample ID	2-Methyl-naphthalene (µg/g)	Acetone (µg/g)	Bis(2-ethyl-hexyl) phthalate (µg/g)	DDE (µg/g)	DDT (µg/g)	Naphthalene (µg/g)	PCB-1260 (µg/g)	TPH as Diesel (µg/g)
RBC	**230[a]**	**780**	**46**	**1.9**	**1.9**	**310**	**0.083[b]**	**100[c]**
MW-55	ND	ND	0.26	0.01	0.04	ND	0.29	ND
MW-56	ND	ND	0.18	ND	ND	ND	ND	ND
MW-57	ND	ND	0.56	ND	ND	ND	0.39	ND
MW-58	ND	0.02	0.22	ND	ND	ND	0.02	ND
MW-85	ND	ND	ND	ND	ND	ND	0.339	ND
RISB-3	ND	ND	ND	ND	ND	ND	0.70	ND
RISB-4	ND	ND	ND	ND	ND	ND	0.48	ND
RISB-5	ND	ND	ND	ND	ND	ND	0.12	ND

[a] The RBC for pyrene was used as a surrogate for noncarcinogenic polycyclic aromatic hydrocarbons (PAHs) lacking RBCs.

[b] Value is for carcinogenic PCBs.

[c] VDEQ action level

-- No value available.

ND Not detected.

RBC USEPA Region III residential risk-based concentration (RBC) values.

Table 2-12 (Continued)
Inorganics Detected in Subsurface Soil Samples (2 ft to Water Table)
Collected in AREEs 11 and 17 North of the Main Compound

Sample ID	Depth bgs (ft)	Aluminum (µg/g)	Arsenic (µg/g)	Barium (µg/g)	Beryllium (µg/g)	Calcium (µg/g)	Chromium (µg/g)
Site Background		**18,200**	**ND**	**73.8**	**1.02**	**454**	**25.0**
RBC		**7,800**	**0.43**	**550**	**0.15**	**--**	**39**
MW-55	12	14,300	ND	112	1.20	1,030	23.2
	15	12,300	ND	88.6	1.29	1,370	30.3
MW-56	10	6,730	ND	52.7	0.59	722	13.4
	15	18,500	0.95	79.7	0.58	640	26.6
MW-57	5	10,800	ND	77.3	0.69	445	15.9
	15	5,290	ND	ND	0.26	433	13.6
MW-57Dup	15	4,080	ND	ND	ND	333	10.5
MW-58	5	4,220	ND	ND	ND	139	7.99
	7	5,090	ND	ND	ND	238	9.44
MW-85	10	3,670	ND	ND	0.341	326	9.94
RISB-3	5	13,400	ND	ND	0.70	223	17.5
RISB-3	10	3,740	ND	ND	0.26	ND	5.63
RISB-4	5	1,800	ND	ND	ND	ND	4.70
RISB-5	5	9,500	ND	57.9	0.43	213	13.6

Table 2-12 (Continued)
Inorganics Detected in Subsurface Soil Samples (2 ft to Water Table)
Collected in AREEs 11 and 17 North of the Main Compound

Sample ID	Depth (ft)	Cobalt (µg/g)	Copper (µg/g)	Iron (µg/g)	Lead (µg/g)	Magnesium (µg/g)	Manganese (µg/g)
Site Background		**13.9**	**16.9**	**27,800**	**11.8**	**3,700**	**617**
RBC		**470**	**310**	**2,500**	**400**	**–**	**180**
MW-55	12	12.1	23.1	5,120	11.9	1,440	62.9
	15	27.8	32.1	14,900	ND	3,950	151.0
MW-56	10	3.53	10.7	5,830	ND	1,400	68.7
	15	4.01	8.69	12,800	13.6	2,250	75.6
MW-57	5	3.69	8.88	19,600	11.0	1,160	99.6
	15	ND	4.88	4,940	ND	1,110	44.3
MW-57Dup	15	ND	4.15	7,680	ND	1,100	43.3
MW-58	5	ND	3.43	3,220	ND	483	66.7
	7	3.22	4.43	3,210	ND	749	45.1
MW-85	10	6.54	8.04	3,220	ND	952	33.1
RISB-3	5	13.3	9.20	17,800	10.1	2,150	363.0
	10	6.58	3.34	8,100	ND	403	188.0
RISB-4	5	ND	2.16	1,830	ND	269	16.6
RISB-5	5	2.67	7.92	13,800	10.2	612	27.5

Table 2-12 (Continued)
Inorganics Detected in Subsurface Soil Samples (2 ft to Water Table)
Collected in AREEs 11 and 17 North of the Main Compound

Sample ID	Depth bgs (ft)	Nickel (µg/g)	Potassium (µg/g)	Selenium (µg/g)	Sodium (µg/g)	Vanadium (µg/g)	Zinc (µg/g)
Site Background		**17.9**	**624**	**–**	**933**	**25.8**	**46.3**
RBC		**160**	**–**	**39**	**–**	**55**	**2,300**
MW-55	12	20.3	495	ND	439	40.6	30.7
	15	36.0	844	ND	701	63.4	103
MW-56	10	7.78	651	ND	468	28.9	27.8
	15	8.33	558	ND	412	43.7	25.4
MW-57	5	5.30	477	ND	410	43.9	29.0
	15	5.82	245	ND	398	18.1	23.5
MW-57Dup	15	5.06	171	ND	383	15.0	22.1
MW-58	5	2.52	188	ND	299	10.7	7.69
	7	3.29	314	ND	325	11.1	10.8
MW-85	10	5.97	204	ND	362	16.5	11.7
RISB-3	5	7.86	396	16.3	381	40.4	24.8
	10	ND	167	ND	303	10.2	7.91
RISB-4	5	ND	124	ND	266	4.96	ND
RISB-5	5	3.71	403	13.7	378	29.0	18.3

– No value available.

ND Not detected.

RBC USEPA Region III residential risk-based concentration (RBC) values.

Table 2-12 (Continued)
Organics Detected in Subsurface Soil Samples (2 ft to Water Table)
Collected in AREEs 11 and 17 North of the Main Compound

Sample ID	Depth bgs (ft)	2-Methyl-naphthalene (µg/g)	Acetone (µg/g)	Bis(2-ethylhexyl)-phthalate (µg/g)	Naphthalene (µg/g)	PCB-1260 (µg/g)	Phenanthrene (µg/g)
RBC		**230 [a]**	**780**	**46**	**310**	**0.083 [b]**	**--**
MW-55	12	ND	0.02	0.33	ND	ND	ND
	15	ND	ND	0.26	ND	ND	ND
MW-57	5	ND	ND	ND	ND	ND	ND
	15	ND	ND	0.21	ND	ND	ND
MW-57DUP	15	ND	0.01	0.44	ND	ND	ND
MW-58	5	ND	ND	0.37	ND	ND	ND
	7	ND	ND	0.190	ND	ND	ND
MW-85	10	ND	0.030	ND	ND	ND	ND
RISB-3	5	ND	ND	ND	ND	ND	ND
	10	ND	ND	ND	ND	ND	ND
RISB-4	5	ND	ND	ND	ND	ND	ND
RISB-5	5	ND	ND	ND	ND	ND	ND

[a] The RBC for pyrene was used as a surrogate for noncarcinogenic polycyclic aromatic hydrocarbons (PAHs) lacking RBCs.

[b] Value is for carcinogenic PCBs.

ND Not Detected.

-- No value available.

RBC USEPA Region III risk-based concentration (RBC) values.

Table 2-13
Inorganics Detected in Groundwater Samples Collected in AREEs 11 and 17 North of the Main Compound

Sample ID	Aluminum µg/L	Arsenic µg/L	Barium µg/L	Cadmium µg/L	Calcium µg/L	Iron µg/L	Lead µg/L
Site Background	**12,500**	**6.70**	**107**	**0.8**	**42,200**	**9,620**	**6.3**
RBC	**3,700**	**0.045**	**260**	**1.8**	**–**	**1,100**	**–**
Round 1							
MW-39	89.1	ND	28.2	ND	3040	199	2.8
MW-55	209	ND	63.6	0.3	2,460	172	ND
MW-56	137	3.0	52.0	ND	3,160	17,200	ND
MW-57	1,320	1.1	32.8	ND	3,690	14,600	ND
MW-58	250	ND	34.9	ND	2,700	239	ND
MW-62	438	5	81.8	ND	5,610	18,000	ND
MW-84	617	ND	54.2	ND	29,000	7,310	ND
MW-85	327	ND	55.9	ND	4,180	8,430	ND
MW-85Dup	398	ND	58.2	ND	4,360	8,880	ND
Round 2							
MW-55	211	ND	56	0.3	1,940	94.8	ND
MW-56	108	3.8	45.9	ND	2,930	15,800	ND
MW-57	1,450	1.9	32.4	ND	4,030	15,000	ND
MW-58	150	ND	ND	ND	2,120	77.2	ND
MW-62	136	4.2	68.7	ND	5,890	15,300	ND
MW-84	330	ND	45.7	ND	19,700	8,600	ND

Table 2-13 (Continued)
Inorganics Detected in Groundwater Samples Collected in AREEs 11 and 17 North of the Main Compound

Sample ID	Magnesium µg/L	Manganese µg/L	Potassium µg/L	Selenium µg/L	Sodium µg/L	Zinc µg/L
Site Background	**7,720**	**354**	**20,600**	**4.2**	**43,500**	**46**
RBC	**--**	**18**	**--**	**18**	**--**	**1,100**
Round 1						
MW-39	3,560	115	1,280	ND	4,370	205
MW-55	4,040	91.5	1,210	ND	6,830	182
MW-56	1,500	399	596	ND	5,930	20.4
MW-57	2,180	411	1,030	ND	6,440	ND
MW-58	2,840	104	831	ND	5,700	42.9
MW-62	1,900	562	968	ND	6,820	ND
MW-84	2,280	279	1,710	ND	8,680	ND
MW-85	1,860	471	743	ND	9,810	94.5
MW-85Dup	1,950	493	806	2.40	10,300	ND
Round 2						
MW-55	4,030	70.8	835	ND	6,800	119
MW-56	1,360	370	628	ND	5,490	ND
MW-57	2,330	434	788	ND	6,530	ND
MW-58	2,800	42.4	1,020	ND	5,180	ND
MW-62	1,660	494	915	ND	6,710	ND
MW-84	1,770	248	1,410	ND	7,770	ND

-- No value available.

ND Not detected.

RBC USEPA Region III residential risk-based concentration (RBC) values.

Table 2-13 (Continued)
Organics Detected in Groundwater Samples Collected in AREEs 11 and 17 North of the Main Compound

Sample ID	1-Methyl naphthalene (µg/L)	2-Methyl naphthalene (µg/L)	Acenaphthene (µg/L)	Acenaphthylene (µg/L)	Acetone (µg/L)	Anthracene (µg/L)
RBC	**110[a]**	**110[a]**	**220**	**110[a]**	**370**	**1,100**
Round 1						
MW-55	ND	ND	ND	ND	ND	ND
MW-56	ND	ND	ND	ND	ND	ND
MW-57	ND	ND	ND	ND	12	ND
MW-58	ND	ND	ND	ND	ND	ND
MW-62	ND	ND	ND	ND	ND	ND
MW-84	ND	ND	2.19	ND	26.0	0.305
MW-85	ND	ND	ND	ND	ND	ND
MW-85-Dup	ND	ND	ND	ND	ND	ND
Round 2						
MW-55	ND	ND	ND	ND	ND	ND
MW-56	ND	ND	ND	ND	ND	ND
MW-57	ND	ND	ND	ND	ND	ND
MW-58	ND	ND	ND	ND	ND	ND
MW-62	ND	ND	ND	ND	ND	ND
MW-84	ND	ND	ND	ND	24	1.20
MW-85	ND	ND	ND	ND	ND	ND

Table 2-13 (Continued)
Organics Detected in Groundwater Samples Collected in AREEs 11 and 17 North of the Main Compound

Sample ID	Bis(2-ethylhexyl) Phthalate (µg/L)	Chloroform (µg/L)	Dieldrin (µg/L)	Endosulfan sulfate (µg/L)	Ethylbenzene (µg/L)	Fluoranthene (µg/L)
RBC	**4.8**	**0.15**	**0.0042**	**22[b]**	**130**	**150**
Round 1						
MW-55	2.1	ND	0.009	0.015	ND	ND
MW-56	ND	ND	ND	ND	ND	ND
MW-57	3.5	ND	ND	ND	ND	ND
MW-58	6.6	ND	ND	ND	ND	ND
MW-62	ND	ND	ND	ND	ND	ND
MW-84	11.0	ND	ND	ND	ND	ND
MW-85	ND	ND	ND	ND	ND	ND
MW-85Dup	2.10	ND	ND	ND	ND	ND
Round 2						
MW-55	ND	ND	ND	ND	ND	ND
MW-56	3.7	ND	ND	ND	ND	ND
MW-57	3.5	ND	ND	ND	ND	ND
MW-58	ND	ND	ND	ND	ND	ND
MW-62	17	ND	ND	ND	ND	ND
MW-84	ND	ND	ND	ND	ND	ND
MW-85	ND	ND	ND	ND	ND	ND

Table 2-13 (Continued)
Organics Detected in Groundwater Samples Collected in AREEs 11 and 17 North of the Main Compound

Sample ID	Fluorene (µg/L)	Naphthalene (µg/L)	Phenanthracene (µg/L)	Phenanthrene (µg/L)	Pyrene (µg/L)
RBC	--	--	**110[a]**		**110**
Round 1					
MW-55	ND	ND	ND	ND	ND
MW-56	ND	ND	ND	ND	ND
MW-57	ND	ND	ND	ND	ND
MW-58	ND	ND	ND	ND	ND
MW-62	ND	ND	ND	ND	ND
MW-84	ND	ND	2.93	ND	0.19
MW-85	ND	ND	ND	ND	ND
MW-85Dup	ND	ND	ND	ND	ND
Round 2					
MW-55	ND	ND	ND	ND	ND
MW-56	ND	ND	ND	ND	ND
MW-57	ND	ND	ND	ND	ND
MW-58	ND	ND	ND	ND	ND
MW-62	ND	ND	ND	ND	ND
MW-84	ND	ND	ND	0.715	ND
MW-85	ND	ND	ND	ND	ND

[a] The RBC for pyrene was used as a surrogate for noncarcinogenic polycylic aromatic hydrocarbons (PAHs) lacking RBCs.

[b] The RBC for endosulfan was used.

-- No value available.

ND Not detected.

RBC USEPA Region III residential risk-based concentration (RBC) values.

Table 2-14
Inorganic Compounds Detected in Sediment Samples Collected from the Main Ditch (OU3)

Sample ID	Aluminum (µg/g)	Barium (µg/g)	Beryllium (µg/g)	Calcium (µg/g)	Chromium (µg/g)	Cobalt (µg/g)	Copper (µg/g)	Iron (µg/g)
Range of Background	**10,500-15,200**	**175**	**0.989-1.26**	**4,240-6,000**	**21.6-30.1**	**14.6-20.7**	**29.8-41.8**	**26,100-34,200**
RISD24	7,210	ND	ND	2,070	25.4	14.8	18.8	19,200
RISD24Dup	6,630	ND	0.615	2,850	25.6	17.4	22.9	20,000
RISD26	15,600	187	1.37	1,330	20.2	8.33	21.5	34,600
RISD27	15,400	117	0.715	2,020	21.2	11.2	19.1	18,200
RISD28	15,200	145	1.02	1,820	22.6	16.7	24	18,800
RISD29	10,600	86.3	1.05	694	15.5	8.19	14	22,500
RISD30	12,500	154	1.93	2,370	18.1	19.1	15.9	17,000
RISD31	9,850	75.8	1.16	1,030	13.5	8.5	12.5	10,300
RISD32	15,900	191	2.44	2,410	23.0	27.3	25.9	19,400
RISD33	8,980	135	1.14	1,710	13.3	20.1	18.3	17,600
RISD34	14,500	173	1.41	2,130	20.6	36.1	23.4	18,100
RISD35	12,500	139	1.03	1,300	19.1	15	19	17,300
RISD36	21,200	236	1.67	3,360	32	22.3	46.7	26,200
RISD37	20,900	ND	ND	5,140	40.5	34.2	59.3	39,700
RISD38	1,740	ND	ND	471	11.3	ND	5.27	6,940
RISD39	952	ND	ND	174	12.1	2.68	2.37	6,740
RISD40	11,500	ND	ND	4,840	24.2	16.7	41.4	20,300

Sample ID	Lead (µg/g)	Magnesium (µg/g)	Manganese (µg/g)	Nickel (µg/g)	Potassium (µg/g)	Sodium (µg/g)	Vanadium (µg/g)	Zinc (µg/g)
Range of Background	**22.8-42.2**	**2,470-3,470**	**911.5-1,690**	**19.3-30.0**	**1,450-2,120**	**932-1,710**	**35.5-52.5**	**114-157**
RISD24	18.4	1,440	357	19.6	781	878	52.3	68.3
RISD24Dup	ND	1,570	449	16.2	666	1,120	62.1	83.5
RISD26	42.6	1200	73.4	13.5	1040	911	68.8	70.1
RISD27	51.9	1830	361	10.4	991	944	46.5	116
RISD28	84.5	1760	315	12.8	840	599	51	194
RISD29	64.3	772	104	8	499	661	49.3	57.6
RISD30	36.4	1,450	391	15.2	843	697	44.1	107
RISD31	20.9	1,010	216	7.72	542	565	28.9	63.2
RISD32	50.6	1,760	424	18.4	818	1,240	57.9	192
RISD33	35.1	1,090	438	11.4	483	890	40.5	123
RISD34	47.5	1,570	564	19.1	782	1,170	43.1	257
RISD35	27.4	1,650	338	13.4	772	1,020	42.5	99.6
RISD36	50.6	3,120	712	24.5	1,410	1,650	72.7	188
RISD37	55.9	3,750	985	35.8	1,810	1,880	83.3	222
RISD38	ND	397	234	3.56	264	531	15.5	26.6
RISD39	ND	224	277	ND	ND	326	19.8	23.3
RISD40	ND	2,540	461	26.4	1,070	2,790	52.6	117

Table 2-14 (Continued)
Organic Compounds Detected in Sediment Samples Collected from the Main Ditch (OU3)

Sample ID	1-Methylnaph-thalene (µg/g)	2-Methylnaph-thalene (µg/g)	Acenaphthene (µg/g)	Alpha-chlordane (µg/g)	Anthracene (µg/g)	Benzo(a) anthracene (µg/g)	Benzo(a) pyrene (µg/g)	Benzo(b) fluoranthene (µg/g)
Range of Background Concentrations	**NA**	**ND**	**0.668-0.919**	**ND**	**0.108-0.169**	**0.0210-0.0310**	**0.0290-0.0515**	**0.0610-0.083**
RISD26	0.888	0.946	<0.133	<0.003	0.057	0.013	0.021	0.029
RISD27	0.721	0.818	<0.133	0.016	0.19	0.049	0.109	0.12
RISD28	<0.133	0.428	<0.133	0.021	0.028	0.035	0.072	0.107
RISD29	0.586	0.564	<0.133	<0.003	0.083	0.009	0.015	0.02
RISD30	0.952	0.721	<0.133	<0.003	0.103	0.18	0.03	0.044
RISD31	<0.133	0.926	<0.133	<0.003	0.023	0.004	0.004	0.009
RISD32	<0.133	1.01	<0.133	<0.003	0.065	<0.013	0.054	0.109
RISD33	0.635	0.574	<0.133	<0.003	0.032	0.034	0.192	0.094
RISD34	1.03	1.24	1.31	<0.003	0.037	0.022	0.098	0.06
RISD35	1.11	1.78	<0.133	<0.003	0.155	0.591	0.596	0.347

Sample ID	Benzo(g,h,i)-perylene (µg/g)	Benzo(k)fluo-ranthene (µg/g)	Benzoic Acid (µg/g)	Chrysene (µg/g)	Chlordane (µg/g)	DDD (µg/g)	Dibenzo(a,h) anthracene (µg/g)
Range of Background Concentrations	**0.0460-0.0800**	**0.0170-0.0320**	**–**	**ND**	**ND**	**ND**	**0.0130-0.022**
RISD24	0.03	ND	ND	0.037	ND	ND	ND
RISD24Dup	0.025	0.012	ND	ND	ND	ND	ND
RISD26	0.028	0.013	3.1	0.039	<0.020	<0.003	<0.003
RISD27	0.091	0.057	<0.70	0.027	<0.020	0.016	0.012
RISD28	0.087	0.054	<0.70	0.032	0.263	<0.003	0.014
RISD29	<0.007	0.01	<0.14	0.026	0.041	<0.003	<0.003
RISD30	0.043	0.022	<0.14	0.064	<0.020	<0.003	<0.003
RISD31	<0.007	0.003	1	0.019	<0.020	<0.003	<0.003
RISD32	0.056	0.048	<0.28	0.115	<0.020	<0.003	<0.003
RISD33	0.021	<0.018	<0.29	0.072	<0.020	<0.003	0.012
RISD34	<0.067	0.02	<0.14	0.095	<0.020	<0.003	<0.033
RISD35	<0.168	0.197	<0.28	0.48	<0.020	0.024	<0.083
RISD36	0.141	0.143	ND	0.463	ND	ND	ND
RISD37	0.09	0.08	ND	0.044	ND	ND	0.022
RISD38	0.031	ND	ND	ND	ND	ND	ND
RISD39	0.011	0.004	ND	ND	ND	ND	ND
RISD40	3.43	ND	ND	ND	ND	ND	ND

Table 2-14 (Continued)
Organic Compounds Detected in Sediment Samples Collected from the Main Ditch (OU3)

Sample ID	Fluoranthene (µg/g)	Fluorene (µg/g)	Gamma-chlordane (µg/g)	Indeno (1,2,3-cd) pyrene (µg/g)	Naphthalene (µg/g)	PCB-1260 (µg/g)	Phenanthrene (µg/g)	Pyrene (µg/g)	TPH, as Diesel (µg/g)
Range of Background concentrations	**0.055-0.094**	**0.157-0.355**	**ND**	**0.0640-0.112**	**0.351**	**ND**	**ND**	**0.0530-0.130**	**NA**
RISD24	0.194	ND	ND	ND	0.342	ND	22.9	0.32	ND
RISD24Dup	0.039	2.94	ND	0.013	20.1	ND	0.191	1.03	ND
RISD26	0.045	0.459	<0.003	0.016	0.858	<0.013	0.126	0.034	31.4
RISD27	0.167	<0.033	0.022	0.061	<0.133	<0.013	0.109	0.219	<8.0
RISD28	0.153	<0.033	0.03	0.072	<0.133	<0.013	0.1	0.128	<8.0
RISD29	0.031	<0.033	<0.003	0.015	<0.133	<0.013	0.103	<0.007	<8.0
RISD30	0.054	<0.033	<0.003	0.012	<0.133	<0.013	0.097	0.078	<8.0
RISD31	0.014	<0.033	<0.003	<0.003	2.9	1.25	<0.033	0.011	<8.0
RISD32	0.136	<0.033	<0.003	0.034	0.558	6.04	<0.033	0.133	<8.0
RISD33	0.104	<0.033	<0.003	<0.083	<0.133	3.45	0.356	0.048	23.5
RISD34	0.137	<0.033	<0.003	<0.033	<0.133	0.54	0.915	0.065	36.2
RISD35	0.768	0.313	<0.003	0.227	0.38	0.043	0.68	0.955	<8.0
RISD36	1.01	ND	ND	0.071	0.88	ND	0.697	1.17	ND
RISD37	0.33	ND	ND	0.861	1.12	ND	ND	0.595	ND
RISD38	0.052	ND	ND	0.023	ND	ND	ND	0.116	ND
RISD39	0.015	ND	ND	0.008	ND	ND	ND	0.011	ND
RISD40	0.246	0.229	ND	0.639	ND	ND	ND	0.18	ND

Sediment samples collected from OU3 were analyzed for TCL VOCs, SVOCs, pesticides/PCBs, TAL metals, PAHs, and TPH.

ND Not detected.

ER-L Effects Range-Low, Long and Morgan, 1990.

[a] Laboratory Reporting Limit.

-- No value available.

Table 2-15
Compounds Detected in Surface Water Samples Collected from the Main Ditch (OU3)

Sample ID	Aluminum (µg/L)	Arsenic (µg/L)	Barium (µg/L)	Cadmium (µg/L)	Calcium (µg/L)	Chromium (µg/L)	Copper (µg/L)	Iron (µg/L)	Lead (µg/L)
Range of Background	**1,230-1,930**	**1[a]**	**37.7-41.8**	**0.5[a]**	**18,800-22,200**	**10.8**	**ND**	**1,905-2,510**	**1.3-1.9**
RISW24	595	ND	31.2	ND	15,700	ND	ND	1,140	1.4
RISW24Dup	800	ND	32.6	ND	15,800	ND	ND	1,500	1.6
RISW26	16,100	2.9	109	0.2	4,840	12.6	7.8	17,300	13
RISW27	11,900	2.7	68.1	0.1	8,250	11.7	6.7	11,600	9.2
RISW28	13,500	<1.0	71.6	<1.0	8,600	12.0	7.8	12,100	<1.0
RISW29	13,900	3.1	69.4	<1.0	8,190	10.9	8.2	12,100	8.8
RISW30	13,700	2.2	69.4	0.1	6,950	10.3	6.5	11,300	7.6
RISW31	13,100	2.5	67.5	0.3	6,580	<10.0	7.3	10,200	7.8
RISW32	13,200	2.1	69.3	0.1	6,070	11.1	6.4	10,300	8.0
RISW33	12,200	2.2	65.8	0.1	6,010	14.8	7.6	10,300	7.6
RISW34	12,800	2.2	70	0.1	5,960	12.2	7.3	10,800	7.9
RISW35	10,500	1.6	58.2	<1.0	4,970	<10.0	5.1	7,900	4.8
RISW36	8,960	1.6	56.4	ND	5,140	10.5	6.8	8,320	5.7
RISW37	9,230	1.2	53.6	ND	5,760	ND	6.7	8,190	5.3
RISW38	2,890	ND	46.1	ND	16,100	ND	ND	4,210	3.0
RISW39	5,510	ND	58.4	0.1	15,200	ND	9.9	6,360	5.6
RISW40	636	ND	25.8	ND	14,100	ND	ND	1,520	1.1

Table 2-15 (Continued)
Compounds Detected in Surface Water Samples collected from the Main Ditch (OU3)

Sample ID	Magnesium (µg/L)	Manganese (µg/L)	Nickel (µg/L)	Potassium (µg/L)	Selenium (µg/L)	Sodium (µg/L)	Thallium (µg/L)	Vanadium (µg/L)	Zinc (µg/L)
Range of Background	**5,970-7,500**	**176-303**	**<15[a]**	**2,870-3,670**	**<2.0[a]**	**12,500-16,500**	**ND**	**ND**	**ND**
RISW24	5,720	186	ND	4,260	2.2	20,500	ND	ND	ND
RISW24Dup	5,800	189	ND	4,180	ND	20,800	ND	ND	ND
RISW26	2,750	403	<15	3,670	<2.0	2,110	0.2	30.1	78
RISW27	2,810	624	<15	4,270	<2.0	2,630	0.2	24.7	41.2
RISW28	2,900	590	<15	4,280	<2.0	2,650	<0.1	26.6	43.6
RISW29	2,840	539	<15	3,950	<2.0	2,520	0.2	28.1	44.4
RISW30	2,660	339	<15	3,520	<2.0	2,370	0.1	25.3	43.7
RISW31	2,550	318	<15	3,530	<2.0	2,350	0.2	24.5	42.8
RISW32	2,530	277	<15	3,610	<2.0	2,170	0.1	24.7	49.5
RISW33	2,500	228	<15	3,570	<2.0	2,130	0.1	24.2	50.4
RISW34	2,570	171	<15	3,590	<2.0	2,170	0.2	25.3	46.2
RISW35	2,460	197	<15	3,990	<2.0	2,330	<0.1	17.5	30.7
RISW36	2,350	145	ND	3,340	ND	2,140	ND	17.9	28.9
RISW37	2,640	225	ND	3,680	ND	2,830	ND	19.9	24.4
RISW38	5,960	677	ND	4,650	2.5	16,500	ND	ND	ND
RISW39	5,320	346	ND	3,640	ND	10,100	ND	14.5	24.7
RISW40	5,130	259	ND	4,810	ND	15,300	ND	ND	ND

Surface water samples collected from OU3 were analyzed for TCL VOCs, SVOCs, pesticides/PCBs, TAL metals, PAHs, and TPH.

ND Not detected.

a Laboratory Reporting Limit.

3.0 HUMAN HEALTH RISK ASSESSMENT

3.1 PURPOSE AND APPROACH

This section of the FFS presents the HHRA which evaluates the probability and magnitude of adverse effects on human health associated with actual or potential exposure to site-related chemicals at OU3 of WRF. OU3 consists of the Main Drainage Ditch that runs from the northern property boundary to the point where it discharges into the Belmont and Occoquan bays, as well as the area that is located between the Main Drainage Ditch and the north side of the Main Compound where PCB-contaminated soils were removed in 1995. The location of OU3 is presented in Figure 2-20. The northern branch of the Main Drainage Ditch receives discharge from an area north of the facility boundary as well as runoff from on-site areas. The northwestern branch originates close to the main entrance of WRF and receives runoff predominantly from on-site locations. The two branches converge approximately 1,000 feet east of the western facility boundary. Following the convergence of the north and northwestern branches, the Main Drainage Ditch flows approximately 1,500 feet adjacent to the Main Compound area, where it receives discharge from a ditch that drains the Main Compound area. The Main Drainage Ditch travels roughly 1,000 feet further to the east and turns abruptly to the south, where it crosses under Charlie Road. The Main Drainage Ditch continues to the south, ultimately discharging to the Occoquan/Belmont Bay.

This focused HHRA is based on analyzed data collected by ICF KE and Earth Tech. This HHRA is consistent with Section 300.430(d)(4) of the NCP, which directs that a Baseline HHRA be conducted to characterize the current and potential threats to human health and the environment that may be posed by contaminants migrating to groundwater or surface water, releasing to air, leaching through soil, remaining in the soil, and bioaccumulating in the food chain. This section of the NCP was applied to the WRF OU3 HHRA, in which human health effects associated with site-related chemicals in specific media (surface water, sediment, fish, groundwater, surface soil, and subsurface soil) were evaluated. This HHRA also is consistent with guidance and standards developed by the USEPA (USEPA, 1986a,b, 1989a,b, 1991a, 1992c,d,e) and USEPA Region III. In addition, the methodologies for conducting the HHRA have been discussed with USEPA Region III and the VADEQ in correspondence and a meeting.

The remainder of this HHRA is organized as follows:

- **Identification of Chemicals of Potential Concern (COPCs) (Section 3.2).** The chemicals detected in sediment, surface water, fish, groundwater, surface soil, and subsurface soil are identified and discussed. The analytical data are summarized by presenting the frequency of detection and the range of detected concentrations in site and background samples. COPCs are selected for quantitative evaluation in the human health risk evaluation based on an evaluation of the data, a comparison of maximum site concentrations to USEPA Region III RBCs, and a comparison of site and background concentrations for inorganic chemicals.
- **Human Exposure Assessment (Section 3.3).** The potential pathways through which individuals may be exposed to COPCs in sediment, surface water, fish, groundwater, surface soil, and subsurface soil are discussed and exposure pathways are selected for evaluation. The chemical concentrations at the points of potential exposure are presented for each pathway selected for quantitative evaluation. Assumptions are made for the magnitude, frequency, and duration of exposure for each pathway and potential exposures (intakes) are then quantified.
- **Toxicity Assessment (Section 3.4).** The potential toxicity of chemicals to humans and the chemical-specific health effects criteria to be used in the quantitative assessment are presented.
- **Risk Characterization (Section 3.5).** Quantitative risk estimates are developed for each exposure pathway selected for evaluation by combining the toxicity criteria with estimated intakes of potentially exposed individuals.
- **Uncertainties (Section 3.6).** Major sources of uncertainty in the HHRA are discussed.

- **Summary and Conclusions (Section 3.7).** The HHRA is summarized and the conclusions are presented.

3.2 IDENTIFICATION OF CHEMICALS OF POTENTIAL CONCERN

This section of the HHRA discusses the methodology used to summarize the data (Section 3.2.1) and the methodology used to select COPCs for detailed evaluation in the HHRA (Section 3.2.2). The summarization of data and the selection of COPCs are then presented for each medium in Sections 3.2.3 through 3.2.8. Finally, a summary of the COPCs selected in all media is provided in Section 3.2.9.

3.2.1 Methodology for Data Summary

The first step in the HHRA process was to summarize the analytical data collected during the RI.[1] The following steps, which are in accordance with USEPA (1989a) guidance, were used to summarize the analytical data for this HHRA:

- Analytical data were summarized by environmental medium (i.e., sediment, surface water, fish, groundwater, surface soil, and subsurface soil). The data summary for each environmental medium is described later in this section.
- Analytical data for all media except fish were compared to blank (laboratory, field, and trip) concentration data. If the detected concentration in a site-related sample was less than 10 times (for common laboratory contaminants) or five times (for all other compounds) the concentration in the corresponding blank sample, the sample was qualified with a B (i.e., the analyte was found in the method or QC blank as well as the sample). In accordance with USEPA Region III, B-qualified data were rejected and were not used to determine the arithmetic mean of detected concentrations. Data that were rejected (R-qualified) by the laboratory were not used in the HHRA. Data that were considered estimated values (e.g., J-qualified) were used in the HHRA without modification.
- Data from duplicate samples (samples collected from the same sample location at the same time) were averaged together and treated as one result. If a chemical was detected in only one of two duplicate samples, the detected value was averaged with one-half the quantitation limit of the nondetect sample, and the result was counted as one detect sample.
- Mean chemical concentrations for a given medium were calculated by averaging the detected concentrations with one-half the sample quantitation limit of the nondetects. One-half the sample quantitation limit is typically used in HHRA (USEPA, 1989a) when averaging non-detect concentrations because the actual value can be between zero and a value just below the sample quantitation limit. This procedure also was used when the non-detect sample quantitation limit was two or more times higher than the maximum detected concentration in that medium. The uncertainties associated with using one-half the sample quantitation limit for non-detects will be discussed in the Uncertainty Section of the report.
- Frequency of detection was calculated as the number of samples in which the chemical was detected over the total number of samples collected for the particular grouping.

3.2.2 Selection of Chemicals of Potential Concern

Once the sampling data from OU3 were grouped and summarized, COPCs were selected. The purpose of selecting COPCs is to identify those chemicals that are present as a result of past activities at the site and most likely to be of concern to human health. Therefore, a screening process was used in the HHRA to eliminate: 1) chemicals present at concentrations below levels of concern (as represented by an RBC screening); 2) chemicals present at or below naturally occurring background levels; or 3) essential human nutrients that were present at concentrations below levels of concern. The following methodology was used to conduct these screenings.

[1] It should be noted that additional validation to the data is planned, and will be conducted by an independent contractor at a later date.

- The maximum detected concentrations of organic and inorganic compounds were compared to USEPA Region III RBCs, in accordance with Region III guidance (USEPA, 1995a). The RBCs are health-protective chemical concentrations that are back-calculated using toxicity criteria, a $1x10^{-6}$ target risk level or a 0.1 hazard index, and conservative exposure parameters. A hazard index of 0.1, instead of 1.0, was used to ensure that compounds that could combine to result in a hazard index greater than 1 were not eliminated from evaluation. If the maximum detected on-site chemical concentration was less than the relevant RBC, the probability of contracting cancer would be less than 1 in 1 million and adverse non-carcinogenic effects would not be expected to occur. As a result, these chemicals were eliminated from further evaluation.

  Residential soil RBCs were used to screen surface soil and sediment concentrations, since residential exposures were evaluated in the HHRA. Subsurface soil concentrations were screened using industrial soil RBCs, since the most likely receptors to subsurface soil would be excavation workers (see Exposure Assessment). Tap water RBCs were used to screen groundwater concentrations; in addition, because RBCs are not available for surface water, tap water RBCs were conservatively used for comparison to surface water chemical concentrations, even though the surface water from OU3 is not used for drinking water purposes. Finally, fish concentrations were compared to fish tissue RBCs. RBCs for all chemicals detected at OU3 are presented in Table 3-1.

  RBCs are not available for four essential human nutrients, i.e., calcium, magnesium, sodium, and potassium. These chemicals were eliminated as COPCs if they were present at concentrations that would not be likely to cause adverse effects, i.e., below allowable daily intakes (ADIs).

  RBCs are not available for lead, since no toxicity criteria exist for this chemical. Therefore, other available lead screening criteria were used instead of RBCs for the purposes of screening lead in the HHRA. For sediment and soil, the residential soil screening level of 400 mg/kg (USEPA, 1994b) was used, while for surface water and groundwater, the lead action level of 15 μg/L was used.

- In accordance with USEPA (1989a), inorganic chemicals present at naturally occurring levels may be eliminated from quantitative HHRA. Therefore, an additional screening was conducted for inorganic compounds that were elevated above RBC levels. In order to determine if detected levels of inorganic compounds present at concentrations exceeding RBCs were representative of naturally occurring background levels, on-site data were statistically compared to site-specific background data for each medium.

  The site and background data were first tested using the Shapiro-Wilks test to determine the distribution type of the data sets. For normally or log-normally distributed data, a two-tailed variance ratio test (the F test) was performed to determine if the variances of the on-site and background data sets were similar. If the variances for the two data sets were found to be similar, then the one-tailed pooled variance t-test was considered appropriate to test for similarity between on-site and background levels. If on-site and background variances were found to differ significantly, or if the data were determined to be neither normally nor log-normally distributed, then a nonparametric test (the one-tailed Mann-Whitney test) was used to test for similarity between on-site and background levels. All statistical tests were performed using a significance level of 95% (alpha = 0.05) and are described in detail by Zar (1984). Statistical tests for log-normally distributed data were performed using natural log-transformed monitoring data. Those inorganic compounds that were considered to be statistically within background levels were eliminated from further consideration.

  In accordance with USEPA Region III policy, inorganic compounds that were present at concentrations within background levels, but greater than their RBCs, were evaluated separately from risks associated with COPCs that both exceeded background and RBCs. Risks for these chemicals are discussed in the Uncertainty Section.

- Some analytes collected during the sampling events were not presented or evaluated in the HHRA, including TPH (for which no toxicity criteria are available) and some water and sediment quality parameters (i.e., moisture for sediment samples; hardness and suspended sediment for surface water samples). Section 2 of the FFS should be referred to for samples in which these analytes were analyzed for, and for a summary of these data.

The following sections discuss and summarize the sediment, surface water, fish tissue, groundwater, surface soil, and subsurface soil data that were used in the HHRA, and present the selection of COPCs in each grouping.

3.2.3 Sediment

Sediment samples from OU3 were collected from the portion of the Main Drainage Ditch adjacent to the Main Compound Area, as well as from two ditches in the north/northwestern portion of the site that drain into the Main Drainage Ditch adjacent to the Main Compound. A review of the sediment data indicated that the sediment samples collected in the Main Drainage Ditch, directly north of the Main Compound (i.e., RISD31 through RISD35) had elevated levels of PCBs. Historical information indicates that PCBs from the former oil/water separator and the former washrack at the Main Compound had been released and transported to the Main Drainage Ditch. Consequently data from these samples were grouped together for the purposes of the HHRA and the area was designated as the PCBs Area. The sediment samples collected to the north and northwest of the Main Compound (RISD26 through RISD30) were upgradient and unaffected by the PCB contamination, but were instead affected by pesticides contamination that were likely due to past pesticide applications along the perimeter and/or upgradient of the WRF. These samples were grouped separately, and were designated as the Pesticides Area. Evaluating these two groups will allow a separate assessment of the PCBs Area and the portion of the drainage ditches where pesticides were detected. Evaluating two groupings instead of one large grouping will ensure that PCB and pesticide reasonable maximum exposure (RME) concentrations are not diluted over the entire drainage ditch area.

As discussed in Section 2.0 of the FFS, five background sediment/surface water samples were collected from Mason Neck Wildlife Refuge, which is located away from potential source areas and unaffected by past activities at WRF. The range of concentrations for chemicals detected in background sediment samples is presented in the data summary table for both sediment groupings to show how the site concentrations compare to the background levels. The background inorganics data were statistically compared to site concentrations to determine which inorganics could be considered within background levels. Even though organics were detected in background samples, no organics were eliminated from evaluation based on their presence in background samples (USEPA, 1989a).

The following sections summarize the sediment data collected from the PCBs and Pesticides Area groupings. The data summaries provide the frequency of detection, the arithmetic mean, the range of chemical-specific detection limits, the range of detected concentrations, the residential soil RBCs, and the range of background concentrations for all chemicals detected in sediment. Chemicals that were retained for quantitative evaluation based on the comparison of site concentrations to RBCs and to background concentrations were marked with an asterisk (*) in the data summary table.

3.2.3.1 PCBs Area

Sediment samples from the PCBs Area included RISD31 through RISD35. Samples RISD31 through RISD34 were analyzed for TCL VOCs, SVOCs, pesticides/PCBs, TAL metals, polynuclear aromatic hydrocarbons (PAHs), and PCTs; sample RISD35 was analyzed for all the same analytes, except PCTs. The data summary for chemicals detected in the PCBs Area is presented in Table 3-2.

As shown in Table 3-2, 19 organics were detected in the PCBs Area, 16 of which were PAHs. All organic chemicals, except for benzo(a)pyrene and PCB-1260, had maximum detected concentrations that were below their respective USEPA Region III residential soil RBCs, and thus were eliminated from evaluation in the HHRA. Benzo(a)pyrene and PCB-1260 were the only organic chemicals that were selected for quantitative evaluation from the PCBs Area.

Fifteen inorganic chemicals were detected in sediment from the PCBs Area and are summarized in Table 3-2. A comparison of maximum detected concentrations to Region III residential soil RBCs (or

to allowable daily intake levels for essential human nutrients and the USEPA residential screening level for lead) indicated that the only inorganics that exceeded respective screening levels were aluminum, beryllium, iron, manganese, and vanadium. The remaining inorganic chemicals were, therefore, eliminated from further evaluation in the HHRA.

The next step of the selection process for chemicals detected in the PCBs Area sediment was to conduct a comparison of PCBs Area sediment concentrations to site-specific background concentrations for those inorganic chemicals that exceeded residential soil RBCs. The statistical comparison indicated that all five inorganic chemicals that exceeded RBCs were within background levels.

Based on the screening of all chemicals detected in the PCBs Area sediment to residential soil RBCs and of inorganic chemicals to background levels, the only site-related chemicals selected for quantitative evaluation in the HHRA were benzo(a)pyrene and PCB-1260. As requested by USEPA Region III, any inorganic chemicals that exceeded RBCs but were within background levels were evaluated separately from site-related chemicals. Accordingly, exposures and risks associated with aluminum, beryllium, iron, manganese, and vanadium were evaluated separately from site-related chemicals.

3.2.3.2 Pesticides Area

Sediment samples from the Pesticides Area included RISD26 through RISD30, and all samples were analyzed for TCL VOCs, SVOCs, pesticides/PCBs, TAL metals, and PAHs. As shown in Figure 2-28, two of the sediment samples (RISD26 and RISD29) were collected in the northwestern ditch, two of the sediment samples (RISD27 and RISD28) were collected in the northern ditch, and one sediment sample (RISD30) was collected upgradient of the PCBs Area, but downgradient of the convergence of the two upgradient ditches. The data summary for chemicals detected in the Pesticides Area is presented in Table 3-2.

As shown in Table 3-2, 16 organics were detected in sediment from the Pesticides Area, including 12 PAHs, three pesticides, and one semivolatile. A comparison of maximum detected organic chemical concentrations to USEPA Region III residential soil RBCs indicated that only benzo(a)pyrene was detected above its respective RBC. Therefore, benzo(a)pyrene was the only organic chemical from the Pesticides Area that was selected for quantitative evaluation in the HHRA.

Also shown in Table 3-2, 16 inorganic chemicals were detected in sediment from the Pesticides Area. A comparison of maximum detected concentrations to USEPA Region III residential soil RBCs (or to allowable daily intake levels for essential human nutrients and the residential screening level for lead) indicated that the same inorganics that exceeded respective screening levels for the PCBs Area (i.e., aluminum, beryllium, iron, manganese, and vanadium) exceeded screening levels in the Pesticides Area. The remaining inorganic chemicals were therefore eliminated from further evaluation in the HHRA.

The next step of the selection process was to compare sediment concentrations to site-specific background concentrations for those inorganic chemicals that exceeded residential soil RBCs. The statistical comparison indicated that, once again, all five inorganic chemicals that exceeded RBCs were within background levels.

Based on the screening of all chemicals detected in the Pesticides Area sediment, the only site-related chemical selected for quantitative evaluation in the HHRA was benzo(a)pyrene. As requested by USEPA Region III, inorganic chemicals that exceeded RBCs but were within background levels were evaluated separately from site-related chemicals. Therefore, exposures and risks associated with aluminum, beryllium, iron, manganese, and vanadium were evaluated separately from site-related chemicals.

3.2.4 Surface Water

Surface water samples from OU3 were collected at the same locations as the sediment samples for the PCBs and Pesticides Areas. Surface water data were grouped into samples collected from each of these two areas, identical to the two sediment groupings. Only unfiltered (i.e., total) inorganics surface water concentrations were collected from site and background locations. It should be noted that north

and upgradient of OU3 at WRF is an area where development for a new golf course and residential housing is occurring, and that the surface water samples from both the Pesticides and PCBs Area were collected during or soon after a storm event. It is, therefore, possible that runoff from the construction site could have caused the surface water samples from the PCBs and Pesticides Areas to have elevated levels of suspended sediment. Uncertainties associated with elevated inorganics surface water concentrations due to upgradient construction activities will be discussed in the Uncertainty Section.

As discussed in Section 2.0 of the FFS, five background surface water samples were collected from the same locations as the sediment samples, away from potential source areas and unaffected by activities at WRF. The range of concentrations for chemicals detected in background surface water is presented in the data summary table for both surface water groupings to show how the site concentrations compare to the background levels. Background inorganics data were statistically compared to site concentrations to determine which inorganics could be considered within background levels.

The following sections summarize the surface water data that were collected at OU3. Table 3-3 is a summary table that presents the frequency of detection, the arithmetic mean, the range of chemical-specific detection limits, the range of detected concentrations, USEPA Region III tap water RBCs, and the range of background concentrations for all chemicals detected in surface water. Chemicals that were retained for quantitative evaluation based on the RBC comparison and the comparison of site and background concentrations were marked with an asterisk (*) in the data summary table.

3.2.4.1 PCBs Area

Five surface water samples were collected from the PCBs Area at the same locations as the sediment samples (i.e., RISW31 through RISW35). Samples RISW31 through RISW34 were analyzed for TCL VOCs, SVOCs, pesticides/PCBs, TAL metals, and PCTs, while RISW35 was analyzed for all these compounds, except for PCTs. The data summary for chemicals detected in PCBs Area surface water is presented in Table 3-3.

As shown in Table 3-3, 15 inorganics were detected in the PCBs Area; no organics were detected. A comparison of maximum detected concentrations to USEPA Region III tap water RBCs (or to allowable daily intake levels for essential human nutrients and the USEPA action level for lead) indicated that the only inorganics that exceeded respective screening levels were aluminum, iron, and manganese. The remaining inorganic chemicals were therefore eliminated from further evaluation in the HHRA.

The next step of the selection process was to conduct a comparison of PCBs Area surface water concentrations to site-specific background concentrations for those inorganic chemicals that exceeded tap water RBCs. The statistical comparison indicated that only manganese was within background levels.

Based on the screening of all chemicals detected in the PCBs Area surface water to tap water RBCs and to background levels, the only site-related chemicals selected for quantitative evaluation in the HHRA were aluminum and iron. As requested by USEPA Region III, any inorganic chemicals that exceeded RBCs but were within background levels were evaluated separately from site-related chemicals. Therefore, exposures and risks associated with manganese were evaluated, although separately from site-related chemicals.

3.2.4.2 Pesticides Area

Five surface water samples from the Pesticides Area were collected from the same locations as the Pesticides Area sediment samples. Surface water samples from the Pesticides Area (i.e., RISW26 through RISW30) were analyzed for TCL VOCs, SVOCs, pesticides/PCBs, PAHs, and TAL metals. The data summary for chemicals detected in the Pesticides Area is presented in Table 3-3.

As shown in Table 3-3, one organic and 15 inorganics were detected in the Pesticides Area. A comparison of maximum detected concentrations to USEPA Region III tap water RBCs (or to allowable daily intake levels for essential human nutrients and the USEPA action level for lead) indicated that the only chemicals that exceeded respective screening levels were aluminum, iron, manganese, and vanadium. The remaining chemicals were therefore eliminated from further evaluation in the HHRA.

The next step of the selection process was to conduct a comparison of Pesticides Area surface water concentrations to site-specific background concentrations for those inorganic chemicals that exceeded tap water RBCs. The statistical comparison indicated that all four inorganics that exceeded tap water RBCs were greater than background levels.

Based on the screening process, the site-related chemicals selected for quantitative evaluation in the HHRA were aluminum, iron, manganese, and vanadium.

3.2.5 Fish

Fish fillet data from samples collected from the Main Drainage Ditch were evaluated in the HHRA. Fish samples were collected in the Main Drainage Ditch, north of the Main Compound, down to about 1,000 feet south of Charlie Road, where a beaver dam is located. At the time samples were collected, it appeared that the beaver dam could prevent most fish species from moving across the barrier. However, it is not known how often the dam may be breached to allow fish into and out of the Main Drainage Ditch. The fish fillet samples included samples BASS1F-5F (Ditch), CARP1F-3F (Ditch), CRAPPIE1F-5F (Ditch), EEL1F-5F (Ditch), SFISH2F[2]-5F (Ditch), and WPERCH 1F-5F (Ditch). It should be noted that although it is likely that most of the fish samples were collected above the beaver dam, there is no documentation that specifies the exact location where each of the fish samples was collected. Therefore, it is possible that some of the fish tissue samples were collected below the beaver dam. The fish tissue from the six species of fish were analyzed for lead, mercury, pesticides/PCBs, and PCTs. Only fillet tissue samples were used in the HHRA, because it was assumed that individuals would consume the fillet portion of the fish, rather than the whole body of the fish.

Similar to the evaluations for surface water and sediment, the following text summarizes the fish tissue samples that were collected, and a summary table (Table 3-4) is presented that provides the frequency of detection, the arithmetic mean, the range of chemical-specific detection limits, the range of detected concentrations, and the fish RBCs for all chemicals detected in fish. Concentrations for the organic chemicals detected in USEPA Region III fish tissue that are presented in Table 3-4 were not normalized to percent lipids for the HHRA because only non-normalized data are appropriate for determination of exposure estimations and risk. Chemicals that were retained for quantitative evaluation based on the RBC comparison were marked with an asterisk (*) in the data summary table.

As shown in Table 3-4, fillet tissue data from six species were collected, and the only chemicals that were detected in each of the fish species were PCB-1260 and DDE. Other chemicals that were detected in at least one species included delta-BHC, chlordane, DDD, mercury, and methoxychlor. A comparison of maximum fish tissue concentrations to fish tissue RBCs indicated that all chemicals for all species, except for alpha-chlordane in carp and methoxychlor and DDE in white perch, were above RBC levels, therefore, these chemicals were retained for evaluation in the HHRA.

It should be noted that pesticide concentrations have been detected in fish collected from regional background locations typically at levels similar to or higher than concentrations detected in fish from OU3 (see Section 4.0 of the FFS for more discussion on regional fish tissue concentrations). In addition, some of the pesticides detected in fish (e.g., chlordane, DDE, delta-BHC, methoxychlor) were not detected in sediment from the PCBs Area (where the fish were collected). DDE, delta-BHC, and methoxychlor also were not detected in sediment from the Pesticides Area. This suggests that the pesticide and PCB concentrations detected in fish may not be completely associated with site-related contamination.

Even though fish tissue data were available for OU3 to determine risks associated with ingestion of fish, in accordance with USEPA Region III, surface water concentrations were compared to Water and Organism Ambient Water Quality Criteria (AWQC). The purpose of the comparison was to determine the potential for risks associated with human exposures due to ingestion of water and organisms from OU3 ditches. As shown on Table 3-5, the only chemicals whose maximum surface water concentrations exceeded the Water and Organism AWQCs were iron and manganese in both the PCBs Area and the Pesticides Area. This indicates that risks associated with exposures to iron and manganese could

[2] Note that sample SFISH1F (Ditch) was lost during shipment, thus no results for this sample were available.

potentially occur to individuals if they were to actually consume surface water and fish from the Main Drainage Ditch Area at OU3 (which, as discussed later in the Exposure Assessment, is an unlikely scenario). However, it should be noted that at the time that surface water samples were collected, the area immediately north of WRF was being cleared for a golf course and a housing development, contributing to a relatively high silt content in the surface water samples. The elevated suspended solids concentrations may have contributed to the exceedances of Water and Organism AWQCs for iron and manganese. In summary, it is difficult to draw any definitive conclusions from the comparison of surface water concentrations in the PCBs and Pesticides Areas to the Water and Organisms AWQC values.

3.2.6 Groundwater

Groundwater samples were collected in the surficial aquifer, downgradient of the Main Compound, to determine the extent of contamination associated with past activities in this area. The samples collected in this area were grouped into the PCBs Area Grouping and included samples MW-39, 55, 56, 57, 58, 62, 84, 85. Two rounds of samples were collected from each well, except MW-39, from which only one round of samples was collected. All groundwater samples used in the HHRA were unfiltered samples and were analyzed for TCL VOCs, SVOCs, pesticides/PCBs, TAL metals, PAHs, and PCTs.

As discussed in Section 2.0 of the OU2 and OU4 FFS, four background wells were installed at WRF, from which two rounds of groundwater samples were collected: MW-52, on the northwest side of WRF; MW-53, on the northern boundary of WRF; and MW-54, on the south side of Bayview Road. In addition, three rounds of groundwater samples were collected from background sample MW-63, on the northern boundary of WRF. Samples collected from these wells were unaffected by past activities at WRF. The range of concentrations for chemicals detected in background groundwater samples is presented in Table 3-6 to show how the site concentrations compare to the background levels. The background inorganics data were statistically compared to site concentrations to determine whether any of the inorganics detected in groundwater were within background levels. All background samples, except one round of data from MW-63 were analyzed for TCL VOCs, SVOCs, pesticides/PCBs, TAL metals, PAHs, and PCTs. The single round from MW-63 was analyzed for VOCs, SVOCs, and pesticides/PCBs.

The data summary for chemicals detected in the PCBs Area groundwater is presented in Table 3-6. As shown in Table 3-6, seven organics, primarily PAHs and pesticides, were detected in this groundwater grouping. A comparison of maximum detected concentrations to tap water RBCs indicated that only dieldrin was present at concentrations exceeding respective tap water RBCs.

Fourteen inorganic chemicals were detected in PCBs Area groundwater samples. A comparison of maximum detected inorganic concentrations to respective screening criteria indicated that the inorganics that exceeded the criteria were arsenic, iron, and manganese. The next step of the selection process for inorganics was to conduct a statistical comparison of groundwater concentrations to site-specific background concentrations for those inorganic chemicals that exceeded tap water RBCs. The statistical comparison indicated that iron and manganese were detected above background levels, thus were selected as COPCs.

3.2.7 Surface Soil

Surface soil samples were collected from AREEs 11 and 17, because of known PCB contamination in this area of the Main Compound. For the purposes of the HHRA, surface soil samples collected from this area were grouped into the "PCBs Area" grouping.

A total of 11 surface soil samples was collected from the PCBs Area to determine the extent of surface soil contamination associated with past activities in this area. Three of the samples were 0-6 inches surface soil samples collected by ICF KE, three were 0-6 inches surface soil samples collected by Earth Tech, while five were 0-2 feet surface soil samples collected from borings by ICF KE. All surficial soil samples from 0-6 inches and from 0-2 feet were grouped together in the risk assessment. All samples were analyzed for TCL VOCs, SVOCs, pesticides/PCBs, and TAL metals. In addition, PCTs were analyzed for in the ICF KE data (in some cases, PCTs were only analyzed for when PCBs were detected). In addition, PAHs were analyzed for in 0-6 inches surface soil samples.

As discussed in Section 2.0 of the OU2 and OU4 FFS, five background surface soil samples (RISSBK-1, 2, 3, 4, and 5, all collected between 0-6 inches) were collected from locations along the northern and eastern boundary of WRF. In addition, three background 0-2 feet surface soil samples were collected from borings drilled on the northwest side of WRF (MW-52), on the northern boundary of WRF (MW-53), and on the south side of Bayview Road (MW-54). All background surface soil samples were collected from areas that were unaffected by past activities at WRF. The range of concentrations for chemicals detected in background surface soil samples is presented in Table 3-7 to show how the site concentrations compare to the background levels. The background inorganics data were statistically compared to site concentrations to see which inorganic chemicals detected in OU2 and OU4 were within background levels. All background samples were analyzed for TCL VOCs, SVOCs, pesticides/PCBs, TAL metals, and PCTs; in addition, surface soil samples collected from 0-6 inches also were analyzed for PAHs.

The data summary for chemicals detected in surface soil at the PCBs Area is presented in Table 3-7. As shown in Table 3-7, 22 organics were detected in surface soil samples, consisting primarily of PAHs. A comparison of maximum detected concentrations to residential soil RBCs indicated that benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, indeno(1,2,3-c,d)pyrene, and PCB-1260 were detected above respective screening concentrations and were thus selected as COPCs in surface soil.

Eighteen inorganic chemicals were detected in surface soil from the PCBs Area. A comparison of maximum detected inorganic concentrations to respective screening criteria indicated that aluminum, arsenic, beryllium, iron, and manganese were above respective screening levels. The next step of the selection process was to conduct a statistical comparison of surface soil concentrations to site-specific background concentrations for those inorganic chemicals that exceeded residential soil RBCs. The statistical comparison indicated that all of the inorganics detected in the PCBs Area surface soil grouping were present at concentrations within background levels, thus none was selected as a COPC.

3.2.8 Subsurface Soil

Ten subsurface soil samples were collected from the PCBs Area. Subsurface soil samples were collected only by ICF KE, and consisted of all soil samples that were collected at depths below two feet. Samples were analyzed for TCL VOCs, SVOCs, pesticides/PCBs, TAL metals, and PCTs (in some cases, PCTs were analyzed for only where PCBs had been detected).

As discussed in Section 2.0 of the OU2 and OU4 FFS, six background subsurface soil samples from three borings, each at two depths, were collected from borings drilled on the northwest side of WRF (MW-52), on the northern boundary of WRF (MW-53), and on the south side of Bayview Road (MW-54). All background subsurface soil samples were collected from areas that were unaffected by past activities at WRF. The range of concentrations for chemicals detected in background subsurface soil samples is presented in Table 3-8 to show how the site concentrations compare to the background levels. The background inorganics data were statistically compared to site concentrations to see which inorganic chemicals detected in OU2 and OU4 were within background levels. All background samples were analyzed for TCL VOCs, SVOCs, pesticides/PCBs, TAL metals, and PCTs.

The data summary for chemicals detected in subsurface soil at the PCBs Area also is presented in Table 3-8. As shown in Table 3-8, PCB-1260 was the only organic chemical detected in subsurface soil. A comparison of the maximum detected concentration of PCB-1260 to its industrial soil RBC indicated that it was present below its screening level, and was thus not selected for evaluation in the HHRA.

Seventeen inorganic chemicals were detected in subsurface soil from the PCBs Area. A comparison of maximum detected inorganic concentrations to respective screening criteria indicated that none of the detected inorganics was present above respective screening levels, thus no inorganics from the PCBs Area were selected as COPCs.

It should be noted that confirmatory subsurface soil data were collected by IT for the Army Research Laboratory after PCB contamination excavations in the summer of 1995. However, due to the screening-level nature of these data (i.e., field-level data), they were not used in the HHRA.

3.2.9 Summary of Chemicals of Potential Concern

Table 3-9 summarizes the COPCs in all media sampled at OU3. As shown in this table, very few COPCs were identified in sediment (PCB-1260 and benzo[a]pyrene) and surface water (four inorganics), while five organics and one inorganic in fish were selected as COPCs. Dieldrin was the only organic selected as a COPC in groundwater, along with two inorganics. Finally, five PAHs and PCB-1260 were the only compounds selected as COPCs in surface soil. The only compounds that were selected as COPCs in more than one medium include PCB-1260, benzo(a)pyrene, iron, and manganese.

3.3 EXPOSURE ASSESSMENT

In this section, the potential pathways through which individuals may be exposed to COPCs in sediment, surface water, fish, groundwater, and surface soil from OU3 are identified and exposures are quantified (as noted above, no COPCs were selected for subsurface soil). A definition of an exposure pathway (Section 3.3.1) is followed by a discussion of potential exposure pathways through which populations could currently be exposed to COPCs at OU3 (Section 3.3.2). This is followed by a discussion on potential pathways of exposure under future land-use conditions (Section 3.3.3). For each pathway selected for quantitative evaluation, the COPCs concentrations at the points of exposure are estimated, followed by the methodology for calculating potential chemical intakes (Section 3.3.4).

3.3.1 Potential Exposure Pathways

An exposure pathway describes the course a chemical takes from the source to the exposed individual. It is defined by four elements:

- a source and mechanism of chemical release to the environment;
- an environmental transport medium (e.g., sediment) for the released chemical;
- a point of potential contact with the contaminated medium (referred to as the exposure point); and
- an exposure route (e.g., ingestion) at the contact point.

An exposure pathway is considered complete only if all four elements are present, and only complete exposure pathways will be quantitatively evaluated.

When conducting an exposure assessment, USEPA (1989a, 1991a) guidance requires that plausible exposures under both current and future land-use scenarios be evaluated in an HHRA. Accordingly, human exposure pathways are identified for current and potential future land-use conditions at OU3. The current land-use scenario assumes conditions as they currently exist, while the future land-use scenario evaluates potential risks that may be associated with possible changes in site use, assuming no remedial action occurs. In the following sections, information presented previously about COPCs at OU3 is combined with information on population locations, activity patterns, and land use to identify potential human exposure pathways under current and hypothetical future land-use conditions.

3.3.2 Current Land-Use Conditions

The potential exposure pathways through which humans could currently be exposed to contamination resulting from past activities at OU3 are discussed below for each exposure medium. In order to place this discussion into perspective, a description of OU3 is first presented, which provides some background for the exposure pathway analysis.

In general, the area surrounding WRF is residential. Northwest of the facility are former Army family housing units, which are currently used as residential housing; directly to the north, there is a proposed civilian residential development and a golf course. The Occoquan and Belmont Bays are located south and west, respectively, and are popular for recreation.

As described earlier, the areas of evaluation at OU3 consisted of the PCBs Area at the Main Compound and the Pesticides Area, in the north/northwestern portion of the facility. No specific activities occurred in the past for the Pesticides Area, which would have contributed to the contamination detected in this area. Past disposal activities associated with the former washrack and former oil/water separator most likely caused the contamination associated with the PCBs Area. The upper reaches of the

northwestern ditch contains water during runoff periods, while the northern ditch typically contains water. Vegetation along the ditches in the northern portion of OU3 is mostly grassy, with some shrubs. After the ditches converge and as the Main Drainage Ditch passes the Main Compound, and further to the Bay, the ditches contain 1-2 feet of water. The vegetation along the Main Drainage Ditch after the northern and northwestern ditches converge consists of shrubs and larger bushes, and the ditch itself contains vegetation, resulting in a wetlands area. The Main Compound itself consists of buildings, most of which are inactive, surrounded by grassy and paved areas.

Potential exposure pathways through which individuals could currently be exposed to COPCs at OU3 are discussed below and are presented in Table 3-10. Table 3-10 presents the exposure media, exposure points, potential receptors, and exposure routes; indicates whether the pathway is potentially complete; and identifies those pathways that are quantitatively evaluated.

3.3.2.1 Sediment

The most likely potential exposures to COPCs in sediment would be from trespassers who might trespass onto the facility or recreational users who may access the site and wade or play in or around the ditches. Although it is possible that trespassers might wade in OU3 ditches, there are other areas at WRF that are more appealing and would be more amenable to wading and playing. In addition, individuals conducting educational activities could be exposed to COPCs in sediment; however such exposures are currently limited and are similar to those of a trespasser/recreational user, thus were not evaluated under current land-use conditions. Workers are present at WRF under current land-use conditions, but none currently work in the OU3 ditches, and it is therefore unlikely that they would have any reason to contact sediment at OU3. Exposures to workers were therefore not evaluated under current land-use conditions. In summary, a trespasser/recreational user's contact exposures to sediment (i.e., via incidental ingestion and dermal absorption) from the PCBs and Pesticides Areas were quantitatively evaluated in the HHRA under current land-use conditions.

3.3.2.2 Surface Water

The most likely potential exposures to COPCs in surface water would be from trespassers who might trespass onto the facility, recreational users who could access the site and wade or play in the ditches, or environmental educators at OU3. Contact exposures to surface water (i.e., via dermal absorption) from OU3 were quantitatively evaluated in the HHRA for a trespasser/recreational user. Because the ditches are so shallow, swimming would not occur, thus incidental ingestion exposures for surface water were not evaluated. As noted above with sediment, an environmental educator's current exposures are limited, and would be similar to those experienced by trespassers/recreational users and were thus not evaluated under current land-use conditions. For the same reasons provided above for sediment, it is unlikely that contact exposures would occur for workers under current land-use conditions because workers would not likely frequent the ditches; therefore, exposures to these receptors were not evaluated in the HHRA.

3.3.2.3 Fish

Under current land-use conditions, it is not likely that individuals would fish from the OU3 ditches and consume their catch, when there are many other areas at WRF where the fishing would be much better. Therefore, although edible-sized fish were caught from the Main Drainage Ditch, ingestion of fish by individuals (e.g., trespassers, recreational users, or workers) under current land-use conditions was not quantitatively evaluated.

3.3.2.4 Groundwater

Groundwater at the site is not currently being used for drinking water or for any other purposes. As a result, exposures to groundwater would not occur under current land-use conditions, and were not evaluated in the HHRA.

3.3.2.5 Surface Soil

The most likely potential exposures to COPCs in soil would be from trespassers who might trespass onto the facility or recreational users who may access the site. In addition, individuals conducting educational activities could be exposed to COPCs in soil; however such exposures are

currently limited and are similar to those of a trespasser/recreational user, thus were not evaluated under current land-use conditions. Workers are present at WRF under current land-use conditions, but any workers would be present at OU3 to a limited degree, thus exposures to workers were therefore not evaluated under current land-use conditions. In summary, a trespasser/recreational user's contact exposures to surface soil (i.e., via incidental ingestion and dermal absorption) from the PCBs Area were quantitatively evaluated in the HHRA under current land-use conditions.

3.3.2.6 Summary of Pathways Selected for Evaluation Under Current Land-Use Conditions

The exposure pathways quantitatively evaluated under current land-use conditions are the following:

- Incidental ingestion and dermal absorption of COPCs in sediment by a trespasser/recreational user;
- Dermal absorption of COPCs in surface water by a trespasser/recreational user; and
- Incidental ingestion and dermal absorption of COPCs in surface soil by a trespasser/ recreational user.

3.3.3 Future Land-Use Conditions

According to USEPA (1995b), an HHRA evaluating potential future exposures should reflect the most reasonably anticipated future land-uses. WRF will be transferred to the USFWS sometime in the near future. It is assumed that the land-use at the site would not likely change significantly, and the most likely receptors would be USFWS workers and visitors/students. In addition, environmental educators are likely to be at the site for longer periods of time than under current land-use conditions.

In addition, as requested by regulatory agencies and in order to provide a baseline understanding of worst-case risks at OU3, it was also assumed that WRF could become residential. In light of the transfer of WRF to the USFWS, this is considered highly unlikely; nevertheless, for the purposes of the HHRA, it was conservatively assumed that a resident lived at WRF. The future land-use scenarios evaluated in the HHRA assume that no remedial action occurs (i.e., the no action alternative).

Table 3-11 summarizes the potential exposure pathway analysis under future land-use conditions, and presents the exposure media, source and release mechanisms, potential receptors, exposure route, and whether or not the pathway is potentially complete for chemicals at or originating from the evaluated media at OU3.

3.3.3.1 Sediment

Even if WRF were to become residential in the future, it is unlikely that future residents would spend a significant amount of time contacting sediment. Nevertheless, for the purposes of the evaluation, it was assumed that child residents could come into contact with sediment on a regular basis while wading or playing and be exposed to COPCs in sediment via incidental ingestion and dermal absorption. Although adult residents also could be exposed to COPCs in sediment, their exposures are considered much more unlikely, since adults would not be as likely to wade/recreate in the ditches.

Workers could be exposed to COPCs in sediment under future land-use conditions. If any type of construction or maintenance work were to occur in the ditches, contact exposures (e.g., incidental ingestion and dermal absorption) to COPCs in sediment could occur. These pathways were therefore evaluated for future land-use conditions.

Environmental educators also could frequently be exposed to COPCs in sediment during future educational programs, thus contact exposures (e.g., incidental ingestion and dermal absorption) to COPCs in sediment were evaluated for future land-use conditions

Other receptors, including visitors or students, could also contact sediment from the ditches in OU3. However, their exposures would likely be similar to those experienced by trespassers/recreational users, which were evaluated under current land-use conditions. Exposures to visitors and students were therefore not evaluated under future land-use conditions.

3.3.3.2 Surface Water

Similar to sediment exposures, future child residents could be exposed to COPCs in surface water while wading or playing. Because the ditches are shallow, swimming could not occur; therefore, the only potential pathway through which children could be exposed would be via dermal absorption of COPCs in surface water. As noted above, adults would not be likely to frequent the ditches, thus exposures to surface water were not evaluated for hypothetical future adult residents.

Workers could be exposed to COPCs in surface water under future land-use conditions. However, it is unlikely that much work would be conducted with significant water in the ditches. Furthermore, if workers were to contact surface water, the likelihood of significant contact would be quite small, because they would likely wear boots, minimizing surface water contact. Therefore, worker exposures to COPCs in surface water were not evaluated for future land-use conditions.

Environmental educators also could be exposed to COPCs in surface water during future educational programs, thus dermal contact exposures to COPCs in surface water were evaluated for future land-use conditions. As noted above, only dermal exposures would be likely, since the ditches are too shallow for incidental ingestion exposures to occur.

As noted above, other receptors at OU3 ditches include visitors or students. Although they also could contact surface water from the ditches in OU3, their exposures would likely be similar to those experienced by trespassers/recreational users, which were evaluated under current land-use conditions. Exposures to visitors and students were therefore not evaluated again under future land-use conditions.

3.3.3.3 Fish

As noted earlier, fish tissue samples were collected from the PCBs Area at OU3. If residents were to live at WRF, it is possible that they could fish from this area and consume their catch. Although this is unlikely, considering that fishing in the bay, pond, and creeks at WRF would be much more appealing, for the purposes of the HHRA, it was assumed that future residents would hypothetically consume fish caught from the Main Drainage Ditch. Only adults were evaluated for this pathway, since it was assumed that young children would not consume significant amounts of fish.

Although future workers or visitors/students/recreational users could fish at the Main Drainage Ditch, it would not be a very likely exposure scenario, since these receptors would more likely fish in better locations, such as Occoquan Bay and Marumsco Creek. In addition, because this pathway is being evaluated for hypothetical future residents whose exposures would be greater than those of workers or visitors/students/recreational users, ingestion of fish only by future adult residents was evaluated.

3.3.3.4 Groundwater

Future child and adult residents were assumed to be exposed to COPCs in groundwater. Potentially complete exposure pathways for both child and adult residents include ingestion of drinking water and dermal absorption of COPCs in groundwater while bathing. In addition, inhalation of VOCs while showering only by adults (since young children would not be as likely to take showers) was considered for evaluation. However, because none of the COPCs selected for evaluation in groundwater were VOCs, inhalation exposures while showering were not evaluated in the HHRA.

If drinking water wells were installed and the site were industrial in nature, workers at OU3 could potentially be exposed to COPCs in groundwater via ingestion. Although dermal exposures also could occur (while washing hands, for example), these exposures would not be as significant due to the small surface area (hands and forearms) and infrequent exposure frequency.

It should be noted that the use of groundwater in the future is considered to be highly unlikely, due to high iron levels, necessitating treatment prior to consumption.

3.3.3.5 Surface Soil

Future child and adult residents were assumed to contact and be exposed to COPCs in surface soil from the PCBs Area grouping. Children could contact COPCs in surface soil while playing, while adults could contact COPCs in surface soil while gardening or performing other activities. Potentially

complete exposure pathways for child and adult residents for surface soil in both areas would be incidental ingestion of soil and dermal absorption of chemicals in soil. Therefore, both pathways were evaluated for hypothetical future child and adult residents. Inhalation exposures were not evaluated for surface soil, since areas are typically paved or grassy, and generation of particulate matter would not occur to a significant degree.

Workers at OU3 could potentially be exposed to COPCs in surface soil while performing maintenance or other activities, thus incidental ingestion and dermal absorption exposures were evaluated for this receptor. In addition, environmental educators at OU3 also could be exposed to COPCs in surface soil during future educational programs. Consequently, incidental ingestion and dermal absorption exposures also were evaluated for this receptor under future land-use conditions.

3.3.3.6 Summary of Pathways Selected for Evaluation Under Potential Future Land-Use Conditions

The exposure pathways quantitatively evaluated under assumed potential future land-use conditions are as follows:

- Incidental ingestion and dermal absorption of COPCs in sediment by child residents;
- Dermal absorption of COPCs in surface water by child residents;
- Incidental ingestion and dermal absorption of COPCs in sediment by workers;
- Incidental ingestion and dermal absorption of COPCs in sediment by environmental educators;
- Dermal absorption of COPCs in surface water by environmental educators;
- Ingestion of fish by adult residents;
- Incidental ingestion and dermal absorption of COPCs in surface soil by child residents;
- Incidental ingestion and dermal absorption of COPCs in surface soil by adult residents;
- Incidental ingestion and dermal absorption of COPCs in surface soil by workers;
- Incidental ingestion and dermal absorption of COPCs in surface soil by environmental educators;
- Ingestion and dermal absorption of COPCs in groundwater by child residents;
- Ingestion and dermal absorption of COPCs groundwater by adult residents; and
- Ingestion of COPCs in groundwater by workers.

3.3.4 Quantification of Exposure

To quantitatively assess potential exposures to COPCs at OU3, estimates of environmental concentrations at the exposure points were combined with information describing the extent, frequency, and duration of exposure for each potential receptor. This section presents how exposure point concentrations were calculated, followed by an overview of the approaches used to quantify exposures for each selected exposure pathway. The approaches used in this section to quantify exposures are consistent with USEPA (1989a, 1992a) guidance.

3.3.4.1 Exposure Point Concentrations

In order to estimate potential exposures and risks associated with site-related chemicals, chemical concentrations at the points of exposure were first determined. According to USEPA (1992a,c), the most appropriate measurement of central tendency for environmental chemical concentrations is the arithmetic mean. To account for uncertainty associated with this value, USEPA guidance requires the use of the 95% upper confidence limit (UCL) on the arithmetic mean concentration for the estimation of the RME risk. The term RME is defined as the maximum exposure that is reasonably expected to occur at a site (USEPA 1989a). The methodology for calculating the UCL for logtransformed data, which is

discussed by Gilbert (1987) and Land (1975), and is presented in USEPA guidance documents (1992a,c), is as follows:

$$UCL_{1-a} = \exp(y + 0.5_{s_y^2} = \frac{S_y * H_{1-a}}{\sqrt{n-1}})$$

where:

UCL	=	upper confidence limit;
α	=	probability of error (0.05);
y	=	mean of the transformed data;
s_y	=	standard deviation of the transformed data;
$(s_y)^2$	=	variance of the data;
H	=	H-statistic (i.e., from Gilbert 1987); and
n	=	number of samples in population.

When the 95% UCL exceeds the maximum measured value, USEPA (1989a) directs that the maximum measured value be used as the exposure point concentration.

As discussed earlier in Section 3.2, the 95% UCL on the arithmetic mean was calculated for each chemical by including nondetects at one-half of their sample-specific quantitation limits. The RME concentrations of each COPC were assumed to represent the concentrations to which receptors could be exposed at OU3. Exposure point concentrations for the COPCs in the sampled media (i.e., sediment, surface water, fish, groundwater, and surface soil) are presented in Table 3-12.

3.3.4.2 Exposure Estimates Under Current Land-Use Conditions

For the ingestion and dermal absorption exposure pathways, quantification of exposure involves the estimation of an average daily dose, expressed in units of mg chemical/kg body weight per day (mg/kg-day). Dose can be defined as an exposure rate to a chemical determined over an exposure period per unit body weight, and is calculated similarly for both ingestion and dermal absorption pathways. There are, however, significant differences in the meaning and terms used to describe dose for the ingestion and dermal pathways. For the ingestion exposure pathways, the doses calculated in this assessment are referred to as "potential doses." The potential dose is the amount of chemical ingested and available for uptake in the body, and is analogous to the administered dose in a dose-response toxicity experiment. For the dermal absorption pathways, the estimated dose is referred to as an "internal dose," and reflects the amount of chemical that has been absorbed into the body and is available for interaction with biologically important tissues.

Average daily doses are estimated differently for chemicals exhibiting noncarcinogenic and carcinogenic effects, since different toxicity criteria are available for carcinogenic effects and noncarcinogenic effects of chemicals (see Section 3.4, Toxicity Assessment). Average daily doses (ADD) for noncarcinogens are averaged over the duration of exposure and, following USEPA (1992a) guidance, are given the acronym ADD for average daily dose. Average daily doses for carcinogens are averaged over a lifetime, and are given the acronym LADD for lifetime average daily dose. LADDs and ADDs for ingestion exposures, or potential doses, are indicated by (L)ADD_{pot}, while LADDs and ADDs for dermal exposures, or internal doses, are indicated by (L)ADD_{int}.

The ADDs and LADDs are estimated using exposure point concentrations of chemicals together with exposure parameters that specifically describe the exposure pathway. ADDs and LADDs for each pathway were derived by combining the selected exposure point concentration (based on the maximum or the 95% UCL on the mean concentration) of each chemical with reasonable maximum values describing the extent, frequency, and duration of exposure (USEPA, 1989a,1992a).

The following sections present equations by which (L)ADDs were calculated for those pathways quantitatively evaluated under current land-use conditions. The assumptions associated with calculating these exposures and the equations used to estimate $ADDs_{pot}$ and $LADDs_{pot}$ for ingestion exposures and $ADDs_{int}$ and $LADDs_{int}$ for dermal absorption exposures are provided below. It was conservatively

assumed that the chemical concentrations in sediment, surface water, and fish would remain constant over the exposure period.

3.3.4.2.1 Incidental Ingestion of Sediment by Trespassers/Recreational Users

Exposures for incidental ingestion of chemicals in sediment by trespassers/recreational users were calculated using the equation and the exposure parameters presented in Table 3-13 and discussed below.

The sediment exposure point concentrations that were used to evaluate ingestion exposures are shown in Table 3-12 for both the PCBs and Pesticides Areas. The standard default value for a soil ingestion rate (100 mg/day) recommended by USEPA (1989a, 1991a) for individuals over the age of six was used for calculating potential incidental ingestion exposures of sediment for trespassers/recreational users at OU3. The age period assumed for trespassers/recreational users was seven to 16 years old. Trespassers/recreational users were conservatively assumed to be at OU3 one time per week during the year (minus two weeks per year away from the home), resulting in a total of 50 days/year. The exposure duration was assumed to be 10 years, based on the age duration evaluated.

One of the several factors affecting the dose calculation for sediment ingestion is a chemical's bioavailability. Ingested chemicals present in a sediment matrix may not be as readily absorbed through the gastrointestinal tract (due to their affinity to the sediment particles) as chemicals ingested in the matrices administered in experimental studies (from which toxicity criteria are derived). The differences in absorption expected between the ingestion of chemicals adsorbed onto sediment in comparison with typical toxicological study conditions can be accounted for by incorporating a bioavailability factor into the exposure equation. However, for this assessment, the bioavailability factors for all the COPCs were conservatively assumed to be 1.0 (assuming that the absorption efficiency was equivalent for the toxicological study matrix and the sediment matrix).

A 50^{th} percentile body weight value of 45 kg for a 7-to-16 year old was used, and was based on age- and gender-weighted data provided in USEPA (1985b). The USEPA (1989a, 1991a) standard default of 70 years for a lifetime was used as the averaging time for carcinogenic exposures. To calculate the potential for noncarcinogenic exposures, the averaging time was the duration of exposure (i.e., 10 years for the 7-to-16 year old).

The RME exposure point concentrations and calculated LADDs for carcinogenic effects due to the incidental ingestion of sediment by trespassers/recreational users are summarized in the Risk Characterization section.

3.3.4.2.2 Dermal Absorption of Chemicals in Sediment by Trespassers/Recreational Users

Exposures due to dermal absorption of chemicals in sediment were estimated using the equation and the exposure parameters presented in Table 3-14 and discussed below.

The chemical concentrations in sediment, as well as the parameters describing the frequency of exposure, duration of exposure, body weight, and averaging time are identical to those used for estimating the ingestion of sediment by a trespasser/recreational user.

Parameters that are specific to the dermal exposure scenario include the area of exposed skin, the amount of sediment adhering to the skin, and amount of chemical absorbed through the skin from sediment. For the trespasser/recreational user scenario, it was assumed that the trespasser's/recreational user's hands, ½ arms (e.g., forearms), ½ legs (e.g., lower legs), and feet would be exposed and available for contact with sediment. Using data from USEPA (1985a), and averaging across gender and age; it was estimated that the exposed skin surface area for 7-to-16 year old trespassers/recreational users would be 4,600 cm^2. Because no sediment-to-skin adherence factor exists, the soil-to-skin adherence factor of 1.0 mg/cm^2-day was used, which is the reasonable upper-bound default value estimated by USEPA (1992b).

The amount of chemical in sediment absorbed through the skin must be estimated in order to calculate dermal doses. For a chemical to be absorbed through the skin from sediment, it must be released from the sediment matrix, pass through the layers of the skin, and enter into the systemic circulation. This series of events is dependent on a number of factors including the characteristics of the

chemical, the concentration in the applied dose, the site of exposure, inter-individual variability, and characteristics of sediment (e.g., particle size and organic carbon content). Data regarding the amount of specific chemicals that may be absorbed through the skin under conditions normally encountered in the environment (and assumed to occur for this assessment) are lacking. While a number of approaches have been developed to estimate absorption of compounds from the sediment matrix, the resulting dose estimates are highly uncertain (USEPA, 1992b). Despite this uncertainty, the dermal absorption factors for COPCs obtained from USEPA (1995c) were used and are presented in Table 3-14.

The RME exposure point concentrations and calculated LADDs for carcinogenic effects due to dermal absorption of COPCs in sediment at the PCBs and Pesticides Areas by trespassers/recreational users are summarized in the Risk Characterization section.

3.3.4.2.3 Dermal Absorption of Chemicals in Surface Water by Trespassers/Recreational Users

Dermal absorption of chemicals while wading were calculated for COPCs in the PCBs and Pesticides Areas surface water by using the equation and exposure parameters presented in Table 3-15.

The surface water concentrations to which trespassers/recreational users could be exposed while wading were presented earlier in Table 3-12. Although chemicals in the dissolved phase would more readily be absorbed into the skin, as opposed to chemicals in the particulate phase, dissolved surface water concentrations were not available for any of the COPCs, and the more conservative total surface water concentrations were used to evaluate dermal absorption of chemicals from surface water. When estimating potential trespasser/recreational user dermal exposures while wading, the surface area was assumed to be 4,600 cm^2, (the same as the body surface area for the sediment dermal absorption pathway). It was also assumed that the trespasser/recreational user contacts surface water one time per day, for each of the 50 days at the site. An exposure duration of 10 years for the trespasser/recreational user was used, based on the trespasser/recreational user's age duration being evaluated.

A body weight of 45 kg for a 7-16 year old was used, based on data summarized in USEPA (1985b). The USEPA (1989a, 1991a) standard default value of 70 years for a lifetime was used as the averaging time for calculating carcinogenic exposures, while the averaging time for calculating noncarcinogenic exposures was equal to the duration of exposure (i.e., 10 years).

The dose absorbed (DA) per unit area per event is a function of chemical concentration in water, the permeability coefficient for that chemical from water through the skin, and exposure time. The DA value is calculated differently, depending on whether a steady-state or nonsteady-state approach is used. Following USEPA (1992b) guidance, a steady-state approach should be used to evaluate dermal absorption of inorganics from an aqueous matrix, while a nonsteady-state approach has been recommended to evaluate dermal absorption of organics in an aqueous matrix. Because no organic COPCs were selected for evaluation in surface water, only the methodology for determining absorption of inorganic chemicals from surface water is presented.

When calculating the absorbed dose for inorganics assuming steady-state conditions, it is assumed that the concentration gradient across all skin layers is constant and the rate that a chemical enters the skin equals the rate that it exits. Under these assumptions, DA can be estimated using the following steady-state equation from USEPA (1992b):

$$DA = C_{SW} * CF_1 * CF_2 * PC * ET$$

where:

- DA = dose absorbed per unit area per event (mg/cm^2-event);
- C_{sw} = chemical concentration in surface water (µg/L);
- CF_1 = conversion factor (1 $L/10^3$ cm^3);
- CF_2 = conversion factor (1 $mg/10^3$ µg);
- PC = chemical-specific dermal permeability coefficient (cm/hr); and
- ET = exposure time (hours/event).

The RME surface water concentrations that were used for the dermal pathway were presented earlier on Table 3-12. The permeability coefficient is defined as a flux value, normalized for concentrations, that represents the rate at which a chemical penetrates the skin (in units of cm/hr). The default permeability coefficient for inorganics was used for all evaluated inorganics (i.e., 10^{-3} cm/hr [USEPA, 1992b]). The assumed exposure time for contact with water was 2 hours/event.

The RME exposure point concentrations and resulting ADDs for noncarcinogenic effects of a trespasser/recreational user's dermal absorption of chemicals in surface water while wading are summarized in the Risk Characterization section.

3.3.4.2.4 Incidental Ingestion of Surface Soil by Trespassers/Recreational Users

Exposures for incidental ingestion of chemicals in surface soil for trespassers/recreational users were calculated using the equation and exposure parameters presented earlier in Table 3-13 and discussed below.

The surface soil exposure point concentrations that were used to evaluate ingestion exposures are shown in Table 3-12. The standard default value for a soil ingestion rate (100 mg/day) recommended by USEPA (1991a) for individuals over the age of six was used for calculating potential incidental ingestion exposures for trespassers/recreational users. The parameters describing the frequency of exposure, duration of exposure, body weight, and averaging time are identical to those used for estimating incidental ingestion of sediment by a trespasser/recreational user. The bioavailability factors for all the COPCs were conservatively assumed to be 1.0 (assuming that the absorption efficiency was equivalent for the toxicological study matrix and the sediment matrix).

The calculated LADDs for carcinogenic effects and ADDs for noncarcinogenic effects due to the incidental ingestion of surface soil by trespassers/recreational users are summarized in the Risk Characterization section.

3.3.4.2.5 Dermal Absorption of Chemicals in Surface Soil by Trespassers/Recreational Users

Internal doses due to dermal absorption of chemicals in surface soil were estimated using the equation and exposure parameters discussed below and presented earlier in Table 3-14.

The chemical concentrations in surface soil, as well as the parameters describing the frequency of exposure, duration of exposure, body weight, and averaging time are identical to those used above when estimating incidental ingestion of surface soil by trespassers/recreational users.

Parameters that are specific to the dermal exposure scenarios include the area of exposed skin, the amount of soil adhering to the skin, and amount of chemical absorbed through the skin from soil. For the trespasser/recreational user scenario, it was assumed that the hands, ½ arms (i.e., forearms), ½ legs (i.e., lower legs), and feet would be exposed and available for contact with soil. Using data from USEPA (1985), and averaging across gender and age, it was estimated that the exposed skin surface area would be 4,600 cm^2, respectively. The soil-to-skin adherence factor was assumed to be 1.0 mg/cm^2-event, the reasonable upper-bound default value estimated by USEPA (1992b). Dermal absorption factors used for the dermal pathway are presented in Table 3-14.

The resulting LADDs for carcinogenic effects and ADDs for the noncarcinogenic effects due to dermal absorption of COPCs in soil are summarized in the Risk Characterization section.

3.3.4.3 Exposure Estimates Under Future Land-Use Conditions

The following sections present equations by which (L)ADDs were calculated for those pathways quantitatively evaluated under hypothetical future land-use conditions. The assumptions and the equations used to estimate (L)ADDs are provided below, by pathway. It was assumed that the chemical concentrations would remain constant over the exposure period.

3.3.4.3.1 Incidental Ingestion of Sediment by Workers

Exposures for incidental ingestion of chemicals in sediment for hypothetical future workers were calculated using the equation and exposure parameters presented in Table 3-16 and discussed below.

The sediment exposure point concentrations to which workers could be exposed were presented earlier on Table 3-12. As noted earlier, it was assumed that future workers could conduct maintenance or construction activities in the OU3 ditches. As a result, the standard default value for a worker's short-term outdoor ingestion exposure for industrial/commercial facilities (480 mg/day) recommended by USEPA (1991a) was used for calculating potential incidental ingestion exposures for future workers. Workers were conservatively assumed to be working and potentially contacting sediment at OU3 for about two months while construction/maintenance activities were taking place, resulting in an exposure frequency of 50 days/year. In addition, the worker was assumed to work in the OU3 ditches on a one-time basis, resulting in an exposure duration of one year. Bioavailability factors were assumed to be 1.0.

An average body weight value of 70 kg for an adult was used for the worker, and is based on data provided in USEPA (1989a, 1991a). The USEPA (1989a, 1991a) standard default of 70 years for a lifetime was used as the averaging time for carcinogenic exposures. To calculate the potential for noncarcinogenic exposures, the averaging time was the duration of exposure (i.e., one year).

The RME exposure point concentrations and calculated LADDs for carcinogenic effects due to the incidental ingestion of sediment by workers are summarized in the Risk Characterization section for both the PCBs and Pesticides Areas.

3.3.4.3.2 Dermal Absorption of Chemicals in Sediment by Workers

Exposures due to dermal absorption of chemicals in sediment by workers were estimated using the equation and exposure parameters discussed below and presented on Table 3-17.

The chemical concentrations in sediment, as well as the parameters describing the frequency of exposure, duration of exposure, body weight, and averaging time are identical to those used for estimating the ingestion of sediment by a worker.

Parameters that are specific to the dermal exposure scenario include the area of exposed skin, the amount of sediment adhering to the skin, and amount of chemical absorbed through the skin from sediment. For the worker scenario, it was assumed that the worker's hands and arms would be exposed and available for contact with sediment. This assumption was based on the likelihood that workers would be wearing pants, but may have their hands and arms exposed. Using data from USEPA (1985b), and averaging across gender and age, it was estimated that the exposed skin surface area for workers would be 3,500 cm^2. Because no sediment-to-skin adherence factor exists, the soil-to-skin adherence factor of 1.0 mg/cm^2-day, which is the reasonable upper-bound default value estimated by USEPA (1992b), was used. As noted earlier, the amount of chemical in sediment absorbed through the skin must be estimated in order to calculate dermal doses. Dermal absorption factors for COPCs were obtained from USEPA (1995c), and are shown in Table 3-17.

The RME exposure point concentrations and calculated LADDs for carcinogenic effects due to dermal absorption of chemicals in sediment by workers are summarized in the Risk Characterization section.

3.3.4.3.3 Incidental Ingestion of Sediment by Environmental Educators

Exposures for incidental ingestion of chemicals in sediment for hypothetical future environmental educators were calculated using the equation and exposure parameters presented in Table 3-18 and discussed below.

The sediment exposure point concentrations to which environmental educators could be exposed were presented earlier on Table 3-12. As noted earlier, it was assumed that future environmental educators could be present at the OU3 ditches conducting educational activities. As a result, the standard default value for an adult's incidental ingestion soil exposure of 100 mg/day (USEPA, 1991a) was used for calculating potential incidental sediment ingestion exposures for future environmental educators. These individuals were conservatively assumed to be potentially contacting sediment at OU3 for 250 days/year, which assumes that they are present at OU3 for 5 days/week, 50 weeks/year (USEPA, 1991a). In addition, the environmental educator was assumed to work as an educator at OU3 for 25 years, which is the upper-bound default value for time spent at one job (USEPA, 1991a). Bioavailability factors were assumed to be 1.0.

An average body weight value of 70 kg for an adult was used for the educator, and is based on data provided in USEPA (1989a, 1991a). The USEPA (1989a, 1991a) standard default of 70 years for a lifetime was used as the averaging time for carcinogenic exposures. To calculate the potential for noncarcinogenic exposures, the averaging time was the duration of exposure (i.e., 25 years).

The RME exposure point concentrations and calculated LADDs for carcinogenic effects due to the incidental ingestion of sediment by environmental educators are summarized in the Risk Characterization section for both the PCBs and Pesticides Areas.

3.3.4.3.4 Dermal Absorption of Chemicals in Sediment by Environmental Educators

Exposures due to dermal absorption of chemicals in sediment by environmental educators were estimated using the equation and exposure parameters discussed below and presented on Table 3-19.

The chemical concentrations in sediment, as well as the parameters describing the frequency of exposure, duration of exposure, body weight, and averaging time are identical to those used for estimating the ingestion of sediment by an educator.

Parameters that are specific to the dermal exposure scenario include the area of exposed skin, the amount of sediment adhering to the skin, and amount of chemical absorbed through the skin from sediment. For the environmental educator scenario, as for the worker scenario, it was assumed that the educator's hands and arms would be exposed and available for contact with sediment. This assumption was based on the likelihood that the individuals would be wearing pants, but may have their hands and arms exposed. Using data from USEPA (1985b), and averaging across gender and age, it was estimated that the exposed skin surface area would be 3,500 cm^2. Because no sediment-to-skin adherence factor exists, the soil-to-skin adherence factor of 1.0 mg/cm^2-day, which is the reasonable upper-bound default value estimated by USEPA (1992b), was used. As noted earlier, the amount of chemical in sediment absorbed through the skin must be estimated in order to calculate dermal doses. Dermal absorption factors for COPCs were obtained from USEPA (1995c), and are shown in Table 3-19.

The RME exposure point concentrations and calculated LADDs for carcinogenic effects due to dermal absorption of chemicals in sediment by environmental educators are summarized in the Risk Characterization section.

3.3.4.3.5 Incidental Ingestion of Sediment by Child Residents

Exposures for incidental ingestion of chemicals in sediment for hypothetical future 1-to-6 year old child residents were calculated using the equation and exposure parameters presented in Table 3-20 and discussed below.

The sediment exposure point concentrations that were used to evaluate ingestion exposures for both sediment groupings are shown in Table 3-12. The standard default value for a soil ingestion rate of 200 mg/day (USEPA, 1989a, 1991a) for children under six was used to evaluate incidental ingestion exposures of sediment for children. The exposure frequency for child residents playing/wading in the OU3 ditches was assumed to be 100 days/year, based on exposures two days/week for 50 weeks/year. The exposure duration for children was assumed to be six years, based on the age period evaluated. As noted earlier, the bioavailability factors for all the COPCs were conservatively assumed to be 1.0.

An average body weight value of 15 kg for children was obtained from USEPA (1991a). The USEPA (1989a, 1991a) standard default of 70 years for a lifetime was used as the averaging time for carcinogenic exposures, while the duration of exposure (i.e., six years) was used as the averaging time for calculating the noncarcinogenic exposures.

The RME exposure point concentrations and calculated LADDs for carcinogenic effects due to the incidental ingestion of sediment by hypothetical future child residents are summarized in the Risk Characterization section.

3.3.4.3.6 Dermal Absorption of Chemicals in Sediment by Child Residents

Exposures due to dermal absorption of chemicals in sediment were estimated for hypothetical future child residents using the equation and exposure parameters discussed below and presented on Table 3-21.

The chemical concentrations in sediment, as well as the parameters describing the frequency of exposure, duration of exposure, body weight, and averaging time are identical to those used above when estimating incidental ingestion of sediment by hypothetical future child residents at OU3.

As noted earlier, parameters that are specific to the dermal exposure scenarios include the area of exposed skin, the amount of sediment adhering to the skin, and amount of chemical absorbed through the skin from sediment. For the child resident exposure scenario, it was assumed that the child's hands, ½ arms (e.g., forearms), ½ legs (e.g., lower legs), and feet could be exposed and available for contact with sediment. Based on data provided in USEPA (1985b), the resulting body surface area was 2,200 cm^2. Because no sediment-to-skin adherence factor exists, the soil-to-skin adherence factor of 1.0 mg-/cm^2-event, which is the reasonable upper-bound default value estimated by USEPA (1992b), was used. The amount of chemical in sediment absorbed through the skin must be estimated in order to calculate dermal doses. The dermal absorption factors for COPCs are presented in Table 3-21, and were obtained from USEPA (1995c).

The RME exposure point concentrations and resulting LADDs for carcinogenic effects due to dermal absorption of COPCs in sediment at OU3 are summarized in the Risk Characterization section for hypothetical future child residents.

3.3.4.3.7 Dermal Absorption of Chemicals in Surface Water by Environmental Educators

Dermal absorption of chemicals in surface water for environmental educators was calculated by using the equation and exposure parameters presented in Table 3-22 and discussed below.

The surface water RME exposure point concentrations to which educators could be exposed are presented on Table 3-12. When estimating potential dermal exposures, the body surface area that was used in the evaluation was 3,500 cm^2 (the same body surface area used for the sediment dermal absorption pathway). In addition, it was assumed that the educator is exposed to surface water in the ditches 100 days/year. Environmental educators were assumed to contact surface water in the ditches one time per day (i.e., one event/day). An exposure duration of 25 years was used, which is the upper bound value for time spent at one job (USEPA 1991a).

A body weight of 70 kg for an adult was obtained from USEPA (1991a). The USEPA (1989a, 1991a) standard default of 70 years for a lifetime was used as the averaging time to calculate carcinogenic exposures, while the duration of exposure (i.e., 25 years) was used as the averaging time to calculate noncarcinogenic exposures.

As described earlier, the DA per unit area per event is a function of chemical concentration in water, the permeability coefficient for that chemical from water through the skin, and exposure time. Inorganics were assumed to have default permeability coefficients of 10^{-3} cm/hr (USEPA 1992b), and the exposure time was assumed to be two hours/event.

The RME exposure point concentrations and resulting ADDs for noncarcinogenic effects of an environmental educator's dermal absorption of chemicals in surface water are summarized in the Risk Characterization section.

3.3.4.3.8 Dermal Absorption of Chemicals in Surface Water by Child Residents

Dermal absorption of chemicals while wading in surface water for hypothetical future child residents were calculated by using the equation and exposure parameters presented in Table 3-23 and discussed below.

The surface water RME exposure point concentrations to which child residents could be exposed are presented on Table 3-12. When estimating potential child dermal exposures while wading, the body surface area that was used in the evaluation was 2,200 cm^2 for the 1-to-6 year old (the same body surface ware used for the sediment dermal absorption pathway). In addition, it was assumed that the child wades in the ditches 100 days/year, based on exposures two days/week for 50 weeks/year. Children were assumed to play in the ditches one time per day (i.e., one event/day). An exposure duration of six years was used for a child, based on the child's age duration being evaluated.

A body weight of 15 kg for a 1-6 year old was obtained from USEPA (1991a). The USEPA (1989a, 1991a) standard default of 70 years for a lifetime was used as the averaging time to calculate carcinogenic exposures, while the duration of exposure (i.e., six years) was used as the averaging time to calculate noncarcinogenic exposures.

As described earlier, the DA per unit area per event is a function of chemical concentration in water, the permeability coefficient for that chemical from water through the skin, and exposure time. Inorganics were assumed to have default permeability coefficients of 10^{-3} cm/hr (USEPA 1992b), and the exposure time was assumed to be two hours/event.

The RME exposure point concentrations and resulting ADDs for noncarcinogenic effects of a child's dermal absorption of chemicals in surface water are summarized in the Risk Characterization section.

3.3.4.3.9 Ingestion of Fish by Adult Residents

Exposures for ingestion of chemicals in fish for hypothetical future adult residents were calculated using the equation and exposure parameters presented in Table 3-24 and discussed below.

The fillet fish tissue exposure point concentrations that were used to evaluate ingestion exposures for all species of fish caught at OU3 are shown in Table 3-12. An ingestion rate of 54 grams/day (which is based on recreational fishing) was obtained from USEPA (1991a) and is used along with an exposure frequency of 350 days/year. The combination of this ingestion rate and exposure frequency is equivalent to two 8-ounce servings of fish per week. Because the OU3 ditch supports small fish (i.e., sunfish were about 4 inches long and about 1-2 ounces; crappie were about 6 inches long, and about 1-3 ounces; carp were about 10-13 inches long and about 12-23 ounces; and eel were about 7-10 inches long and about 1 ounce [see Section 4.0 for more discussion on fish lengths and weights for fish caught at OU3]), it is highly unlikely that it would contain enough fish for hypothetical future residents to consume fish from OU3 at the default recreational fishing exposure rates. Considering that the fillet portion of the fish that would most likely be consumed accounts for less than 50% of the total body weight, it is clear that these fish would not be used for significant consumption. Therefore, the default recreational fishing exposure parameters were adjusted by one-half to reflect lower ingestion rates that would be more relevant for the exposure scenario at the site (i.e., 175 days/year). The exposure duration for adults was assumed to be 30 years, which is the upper-bound value for residential tenure at one residence (USEPA, 1989a, 1991a).

An average body weight value of 70 kg for adults was obtained from USEPA (1989a, 1991a). The USEPA (1989a, 1991a) standard default of 70 years for a lifetime was used as the averaging time for carcinogenic exposures, while the duration of exposure (i.e., 30 years) was used as the averaging time for calculating the noncarcinogenic exposures.

The RME exposure point concentrations and calculated LADDs for carcinogenic effects and ADDs for noncarcinogenic effects due to the ingestion of fish by hypothetical future adult residents are summarized in the Risk Characterization section.

3.3.4.3.10 Incidental Ingestion of Surface Soil by Workers.

Exposures for incidental ingestion of chemicals in surface soil for hypothetical future workers were calculated using the equation and exposure parameters presented in Table 3-25 and discussed below.

The surface soil exposure point concentrations that were used to evaluate ingestion exposures are shown in Table 3-12. The standard default value for a worker soil ingestion rate (50 mg/day) recommended by USEPA (1991a) was used for calculating potential incidental ingestion exposures for worker. The exposure frequency for a worker was assumed to be 250 days/year, a standard default USEPA (1991a) value, assuming exposures five days/week for 50 weeks/year. The exposure duration for adults was assumed to be 25 years, which is the upper-bound value for workers at one job (USEPA, 1991a). Bioavailability factors were assumed to be 1.0.

An average body weight value of 70 kg for an adult was used for the worker, and is based on data provided in USEPA (1989a, 1991a). The USEPA (1989a, 1991a) standard default of 70 years for a

lifetime was used as the averaging time for carcinogenic exposures. To calculate the potential for noncarcinogenic exposures, the averaging time was the duration of exposure (i.e., 25 years).

The RME exposure point concentrations and calculated LADDs for carcinogenic effects due to the incidental ingestion of soil by workers are summarized in the Risk Characterization section.

3.3.4.3.11 Dermal Absorption of Chemicals in Surface Soil by Workers.

Internal doses due to dermal absorption of chemicals in surface soil were estimated using the equation and exposure parameters discussed below and presented on Table 3-26.

The chemical concentrations in surface soil, as well as the parameters describing the frequency of exposure, duration of exposure, body weight, and averaging time are identical to those used above when estimating incidental ingestion of surface soil by hypothetical future workers.

Parameters that are specific to the dermal exposure scenario include the area of exposed skin, the amount of soil adhering to the skin, and amount of chemical absorbed through the skin from soil. For the worker scenario, it was assumed that the worker's hands and arms would be exposed and available for contact with soil. This assumption was based on the likelihood that workers would be wearing pants, but may have their hands and arms exposed. Using data from USEPA (1985b), and averaging across gender and age, it was estimated that the exposed skin surface area for workers would be 3,500 cm^2. The soil-to-skin adherence factor of 1.0 mg/cm^2-day, which is the reasonable upper-bound default value estimated by USEPA (1992b), was used. As noted earlier, the amount of chemical in soil absorbed through the skin must be estimated in order to calculate dermal doses. Dermal absorption factors for COPCs were obtained from USEPA (1995c), and are shown in Table 3-26.

The resulting LADDs for carcinogenic effects and ADDs for the noncarcinogenic effects due to dermal absorption of COPCs in soil are summarized in the Risk Characterization section.

3.3.4.3.12 Incidental Ingestion of Surface Soil by Environmental Educators.

Exposures for incidental ingestion of chemicals in surface soil for hypothetical future environmental educators were calculated using the equation and exposure parameters presented earlier in Table 3-18 and discussed below.

The soil exposure point concentrations to which environmental educators could be exposed were presented earlier on Table 3-12. As noted earlier, it was assumed that future environmental educators could be present at the OU3 conducting educational activities. As a result, the standard default value for an adult's incidental ingestion soil exposure of 100 mg/day (USEPA, 1991a) was used for calculating potential incidental ingestion exposures for future environmental educators. These individuals were conservatively assumed to be potentially contacting sediment at OU3 for 250 days/year, which assumes that they are present at OU3 for 5 days/week, 50 weeks/year (USEPA 1991a). In addition, the environmental educator was assumed to work as an educator at OU3 for 25 years, which is the upper-bound default value for time spent at one job (USEPA 1991a). Bioavailability factors were assumed to be 1.0.

An average body weight value of 70 kg for an adult was used for the educator, and is based on data provided in USEPA (1989a, 1991a). The USEPA (1989a, 1991a) standard default of 70 years for a lifetime was used as the averaging time for carcinogenic exposures. To calculate the potential for noncarcinogenic exposures, the averaging time was the duration of exposure (i.e., 25 years).

The calculated LADDs for carcinogenic effects and ADDs for noncarcinogenic effects due to the incidental ingestion of surface soil by hypothetical future residents are summarized in the Risk Characterization section.

3.3.4.3.13 Dermal Absorption of Chemicals in Surface Soil by Environmental Educators.

Internal doses due to dermal absorption of chemicals in surface soil were estimated using the equation and exposure parameters discussed below and presented earlier in Table 3-19.

The chemical concentrations in surface soil, as well as the parameters describing the frequency of exposure, duration of exposure, body weight, and averaging time are identical to those used above when estimating incidental ingestion of surface soil by hypothetical future environmental educators.

Parameters that are specific to the dermal exposure scenario include the area of exposed skin, the amount of soil adhering to the skin, and amount of chemical absorbed through the skin from soil. For the environmental educator scenario, as for the worker scenario, it was assumed that the educator's hands and arms would be exposed and available for contact with soil. This assumption was based on the likelihood that the individuals would be wearing pants, but may have their hands and arms exposed. Using data from USEPA (1985b), and averaging across gender and age, it was estimated that the exposed skin surface area would be 3,500 cm^2. The soil-to-skin adherence factor of 1.0 mg/cm^2-day, which is the reasonable upper-bound default value estimated by USEPA (1992b), was used. As noted earlier, the amount of chemical in soil absorbed through the skin must be estimated in order to calculate dermal doses. Dermal absorption factors for COPCs were obtained from USEPA (1995c), and are shown in Table 3-19.

The resulting LADDs for carcinogenic effects and ADDs for the noncarcinogenic effects due to dermal absorption of COPCs in soil are summarized in the Risk Characterization section.

3.3.4.3.14 Incidental Ingestion of Surface Soil by Child and Adult Residents.

Exposures for incidental ingestion of chemicals in surface soil for hypothetical future child and adult residents were calculated using the equation and exposure parameters presented in Table 3-27 and discussed below.

The surface soil exposure point concentrations that were used to evaluate ingestion exposures are shown in Table 3-12. The standard default value for a soil ingestion rate (100 mg/day) recommended by USEPA (1991a) for individuals over the age of six was used for calculating potential incidental ingestion exposures for adults, while the surface soil ingestion rate of 200 mg/day (USEPA, 1991a) for children under six was used to evaluate ingestion exposures for children. The exposure frequency for both child and adult residents was assumed to be 350 days/year, a standard default USEPA (1991a) value, assuming exposures seven days/week for 50 weeks/year. The exposure duration for adults was assumed to be 30 years, which is the upper-bound value for residential tenure at one residence (USEPA, 1989b, 1991a). The exposure duration for children was assumed to be six years, based on the age period evaluated. The bioavailability factor was assumed to be 1.0.

An average body weight value of 70 kg for adults and 15 kg for children were obtained from USEPA (1991a). The USEPA (1991a) standard default of 70 years for a lifetime was used as the averaging time for carcinogenic exposures, while the duration of exposure (i.e., 30 years for adults and six years for children) was used as the averaging time for calculating the noncarcinogenic exposures.

The calculated LADDs for carcinogenic effects and ADDs for noncarcinogenic effects due to the incidental ingestion of surface soil by hypothetical future residents are summarized in the Risk Characterization section.

3.3.4.3.15 Dermal Absorption of Chemicals in Surface Soil by Child and Adult Residents.

Internal doses due to dermal absorption of chemicals in surface soil were estimated using the equation and exposure parameters discussed below and presented on Table 3-28.

The chemical concentrations in surface soil, as well as the parameters describing the frequency of exposure, duration of exposure, body weight, and averaging time are identical to those used above when estimating incidental ingestion of surface soil by hypothetical future child and adult residents.

Parameters that are specific to the dermal exposure scenarios include the area of exposed skin, the amount of soil adhering to the skin, and amount of chemical absorbed through the skin from soil. For the residential scenario, it was assumed that the hands, ½ arms (i.e., forearms), ½ legs (i.e., lower legs), and feet would be exposed and available for contact with soil. Using data from USEPA (1985), and averaging across gender and age, it was estimated that the exposed skin surface area for child and adult residents would be 2,200 cm^2 and 6,400 cm^2, respectively. The soil-to-skin adherence factor was assumed to be 1.0 mg/cm^2-event, the reasonable upper-bound default value estimated by USEPA

(1992b). The dermal absorption factors from USEPA (1995b) that were used in this assessment are presented in Table 3-28.

The resulting LADDs for carcinogenic effects and ADDs for the noncarcinogenic effects due to dermal absorption of COPCs in soil are summarized in the Risk Characterization section.

3.3.4.3.16 Ingestion of Groundwater by Child and Adult Residents.

Exposures for ingestion of groundwater by child and adult residents were calculated using the equation and exposure parameters presented in Table 3-29 and discussed below.

The RME exposure point concentrations to which residents could be exposed were presented earlier in Table 3-12. Drinking water ingestion rates used for residents were based on USEPA guidance. The adult ingestion rate of 2 L/day was a standard USEPA (1991a) default value, while the child 1 L/day ingestion rate was based on one-half the adult ingestion rate. Child and adult residents were conservatively assumed to consume groundwater for 350 days/year, which is an USEPA (1991a) standard default value for seven days/week, 50 weeks/year. The duration of exposure for the 1-6 year old child resident was assumed to be six years, based on the child's age duration being evaluated, while the duration of exposure for the adult resident was assumed to be 30 years, which is the USEPA (1989b, 1991a) upper-bound value for residential tenure at one residence.

The body weight value of 70 kg for an adult and 15 kg for the 1- to 6-year old child were obtained from USEPA (1991a). The USEPA (1991a) standard default of 70 years for a lifetime was used as the averaging time to calculate carcinogenic exposures, while the duration of exposure (i.e., 30 years for the adult and six years for the child) was used as the averaging time to calculate noncarcinogenic exposures.

The resulting LADDs for carcinogenic effects and ADDs for the noncarcinogenic effects for groundwater ingestion by future child and adult residents are presented later in the Risk Characterization section.

3.3.4.3.17 Dermal Absorption of Chemicals in Groundwater by Child and Adult Residents

Dermal absorption of chemicals while bathing (for children) or showering (for adults) were calculated for COPCs selected in groundwater by using the equation and exposure parameters presented in Table 3-30.

The groundwater concentrations (see Table 3-12) to which residents could be exposed while bathing or showering were the same as used for the drinking water exposure pathway. Only unfiltered groundwater sample results were available, thus unfiltered inorganic concentrations were used to evaluate the dermal pathway, even though it is more likely that chemicals in the dissolved phase, rather than the total particulate phase would be absorbed through the skin. When estimating potential child and adult dermal exposures while bathing or showering, it was assumed that the entire body was available for contact with water. The surface areas that were used in the evaluation were calculated based on data provided in USEPA (1985), and were 7,000 cm^2 for a 1- to 6-year old and 18,000 cm^2 for an adult. It was also assumed that the resident takes 1 bath or shower per day (i.e., 1 event per day). In addition, exposure parameters including exposure frequency, exposure duration, body weight, and averaging time were identical to those used when evaluating the groundwater ingestion pathway.

As noted earlier, the dose absorbed per unit area per event is a function of chemical concentration in water, the permeability coefficient for that chemical from water through the skin, and exposure time. The DA value is calculated differently, depending on whether a steady-state or nonsteady-state approach is used. Following USEPA (1992b) guidance, a steady-state approach should be used to evaluate dermal absorption of inorganics from an aqueous matrix, while a nonsteady-state approach has been recommended to evaluate dermal absorption of organics in an aqueous matrix.

When calculating the absorbed dose for inorganics assuming steady-state conditions, it is assumed that the concentration gradient across all skin layers is constant and the rate that a chemical enters the skin equals the rate that it exits. Under these assumptions, DA can be estimated using the following steady-state equation from USEPA (1992b):

$$DA = C_{gw} * CF_1 * CF_2 * PC * ET$$

where:

DA = dose absorbed per unit area per event (mg/cm^2-event);

C_{gw} = chemical concentration in groundwater (ug/L);

CF_1 = conversion factor (1 L/10^3 cm^3);

CF_2 = conversion factor (1 mg/10^3 ug);

PC = chemical-specific dermal permeability coefficient (cm/hr); and

ET = exposure time (hr/event).

The permeability coefficient is defined as a flux value, normalized for concentrations, that represents the rate at which a chemical penetrates the skin (in units of cm/hr). The default permeability coefficient for inorganics was used for all evaluated inorganics (i.e., 10^{-3} cm/hr [USEPA, 1992b]). Permeability coefficients for all COPCs in groundwater were presented in Table 3-31. The assumed exposure time for contact with water was assumed to be 0.28 hour, the same length of time as a shower.

As noted above, USEPA (1992b) has recommended the nonsteady-state approach to estimate the dermally absorbed dose of organics from water. This approach accounts for the total amount of chemicals crossing the exposed (outside) skin surface rather than the amount that has traversed the skin and entered the blood during the exposure period (i.e., under a steady-state condition). Therefore, the nonsteady-state approach more accurately reflects normal exposure conditions and accounts for the dose that may enter the circulatory system after the exposure event due the storage of chemicals in skin lipids (USEPA, 1992b). The nonsteady-state approach has been developed for organics for which octanol-water partitioning data are available, thus was applied to the organic COPCs identified in this assessment.

The equations applied to derive DA using the nonsteady-state dermal dose model for organics were dependent on the length of assumed exposure time (ET) in relation to the time required after initial contact of a chemical with the skin for steady-state to be achieved (termed t^*). The value of t^* is dependent on chemical-specific properties, and the appropriate equation to derive t^* for a chemical is dependent on a dimensionless constant reflecting the partitioning properties of that chemical (USEPA 1992b). This constant, termed B, can be derived from the octanol-water partition coefficient (K_{ow}) as follows:

$$B = \frac{K_{o/w}}{10^4}$$

Once B has been derived, t^* can be calculated using the appropriate equation.

If $B \leq 0.1$, then:

$$t^* = 2.4 * \tau$$

where:

tau = lag time (hr)

If $0.1 < B < 1.17$, then:

$$t^* = (8.4 + 6 * \log B) * \tau$$

If $B \geq 1.17$, then:

$$t^* = 6 * (b - \sqrt{b^2 - c^2}) * \tau$$

where:

$$b = \frac{2}{\pi} * (1 + B)^2 - c$$

$$c = \frac{1 + 3 * B}{3}$$

The lag time (tau) is defined for the stratum corneum, the outermost layer of the skin, which is thought to provide the major resistance to the absorption into the circulatory system of chemicals deposited on the skin (USEPA, 1992b). Tau can be derived from the following equation:

$$\tau = \frac{1_{sc}^2}{6 * D_{sc}}$$

where:

l_{sc} = thickness of stratum corneum (10^{-3} cm); and

D_{sc} = diffusivity of a chemical within the stratum corneum (cm^2/hr).

The diffusivity of a chemical within the stratum corneum (D_{sc}) can be estimated from the thickness of the stratum corneum (l_{sc}) and the molecular weight (MW) of the chemical using the following equation:

$$Log \frac{D_{sc}}{1_{sc}} = \_2.72 - 0.0061 * MW$$

Once the time until steady-state (t^*) has been derived, it can be compared to the assumed ET in order to select the appropriate equation to derive the dermal dose (DA). If the exposure time was less than the time until steady-state (i.e., if ET < t^*), the following equation was used:

$$DA = 2 * C_{gw} * CF_1 * CF_2 * PC * \sqrt{\frac{6 * \tau * ET}{\pi}}$$

where:

DA = dose absorbed per unit area per event (mg/cm^2-event);

C_{gw} = chemical concentration in water (ug/L);

CF1 = conversion factor (1 L/10^3 cm^3);

CF_2 = conversion factor (1 mg/10^3 ug);

PC = chemical-specific dermal permeability coefficient (cm/hr); and

ET = exposure time (hr/event).

If the exposure time was greater than the time until steady-state (i.e., if ET > t^*), then the following equation was used:

$$DA = C_{gw} * CF_1 * CF_2 * PC * [\frac{ET}{1+B} + 2 * \tau * \frac{1+3*B}{1+B}]$$

Estimated permeability coefficients (PC) provided in USEPA (1992b) were used for the organic COPCs. If estimated permeability coefficients were not available for organics, permeability coefficients were estimated by USEPA (1992b) using the following equation:

$$\log(PC) = -2.72 + (0.71 * \log K_{ow}) - (0.0061 * MW)$$

All inputs to equations presented above, including permeability coefficients, log K_{ow}s, and molecular weights that were needed to calculate the DA_{event} for all COPCs in groundwater are presented in Table 3-31.

The resulting $LADDs_{int}$ for the carcinogenic effects and the $ADDs_{int}$ for noncarcinogenic effects of a child's and adult's dermal absorption of chemicals while bathing are summarized in the Risk Characterization section.

3.3.4.3.18 Ingestion of Groundwater by Workers

Exposures for ingestion of groundwater by workers were calculated using the equation and exposure parameters presented in Table 3-32 and discussed below.

The RME exposure point concentrations to which workers could be exposed were presented earlier in Table 3-12. The worker ingestion rate of 1 L/day was obtained from USEPA (1991a). Workers were assumed to consume groundwater for 250 days/year, which is an USEPA (1991a) standard default value for working five days/week, 50 weeks/year. The duration of exposure for the worker was assumed to be 25 years, which is the USEPA (1991a) upper-bound value for time spent working at one job.

The body weight value of 70 kg for an adult was obtained from USEPA (1991a). The USEPA (1991a) standard default of 70 years for a lifetime was used as the averaging time to calculate carcinogenic exposures, while the duration of exposure (i.e., 25 years) was used as the averaging time to calculate noncarcinogenic exposures.

The resulting LADDs for carcinogenic effects and ADDs for the noncarcinogenic effects for groundwater ingestion by future workers are presented later in the Risk Characterization section.

3.4 TOXICITY ASSESSMENT

The general methodology for the classification of health effects and the development of health effects criteria is described in Section 3.4.1. This provides the analytical framework for the characterization of human health risks. In Section 3.4.2, the health effects criteria used to derive estimates of risk are presented. These values are combined with dose information for each pathway quantitatively evaluated to predict potential risks associated with exposures to COPCs.

The methodology used for classifying health effects from exposure to chemicals is recommended by USEPA guidance (1986a,b, 1989a, 1995d, 1996). Chronic toxicity criteria were obtained from USEPA's Integrated Risk Information System (IRIS) (USEPA, 1996) and Health Effects Assessment Summary Tables (HEAST) (USEPA, 1995d). These sources list the most recent toxicity values recommended by USEPA for use in HHRAs.

3.4.1 Health Effects Classification and Criteria Development

Separate health criteria are developed for chemicals depending on whether exposure to them may be associated with principally carcinogenic (cancer-causing) or noncarcinogenic effects, or both. This distinction relates to the currently held scientific opinion that the mechanism of action for each

category is different. For assessing risks associated with potential carcinogens, USEPA has adopted the scientific policy position that a small number of molecular events can evoke changes in a single cell, or a small number of cells, that can lead to tumor formation. This is described as a no-threshold initiator mechanism, because it is assumed that there is essentially no level of exposure (i.e., a threshold) to a carcinogen that will not result in some finite possibility of causing cancer. Another assumption stemming from USEPA's science policy is that the dose-response curve is linear at low doses. In reality, this curve can take many shapes depending on the exact biological mechanisms of action of a chemical. The dose-response curve will especially vary if the chemical is behaving as a cancer promotor rather than as an initiator, with the net effect that the most accurate shape may be indicative of a threshold for response.

In the case of chemicals exhibiting noncarcinogenic effects, however, it is believed that organisms have repair and detoxification capabilities that must be exceeded by some critical concentration (threshold) before the adverse effect is manifested. For example, an organ can have a large number of cells performing the same or similar functions that must be significantly depleted before the effect on the organ is realized. This threshold view holds that a range of exposures from just above zero to some finite value can be tolerated by the organism without an appreciable risk of adverse effects.

3.4.1.1 Health Effects Criteria for Potential Carcinogens

For carcinogens, USEPA's Carcinogen Risk Assessment Verification Endeavor (CRAVE) evaluates the excess lifetime cancer risks associated with various levels of exposure by developing cancer slope factors and unit risks. Cancer slope factors are expressed in terms of reciprocal dose, as units of (mg chemical/kg body weight-day)$^{-1}$. They describe the upper-bound increase in an individual's risk of developing cancer over a 70-year lifetime per unit of exposure. Unit risks are expressed either as a reciprocal air concentration in units of (μg/L)$^{-1}$, or as a reciprocal drinking water concentration, in units of (μg /L)$^{-1}$. Similarly, they are defined as the probability of an individual developing cancer over a 70-year lifetime as a result of exposure to one unit of concentration in air or water. Because regulatory efforts are geared to be protective of public health, including even the most sensitive members of the population, the cancer slope factors are derived using conservative assumptions.

Cancer slope factors and unit risks are derived from the results of human epidemiological studies or chronic animal bioassays. The animal studies usually must be conducted using relatively high doses to detect possible adverse effects. Because humans are expected to be exposed to doses lower than those used in the animal studies, the potential cancer risks at lower doses are estimated by using mathematical models. The data from animal studies are typically fitted to the linearized multistage model to obtain a dose-response relationship. In general, after the data are fit to the dose-response model, the 95 percent upper confidence limit of the slope of the resulting dose-response relationship at low doses is calculated. This upper-bound limit is subjected to various adjustments, and an interspecies scaling factor is applied to derive the slope factor or unit risk for humans. Thus, the actual risks associated with a given intake of a potential carcinogen quantitatively evaluated based on animal data are generally regarded as not likely to exceed the risks estimated using these slope factors and unit risks, and they may be as low as zero (USEPA 1986a). Dose-response data derived from human epidemiological studies are fitted to dose-time-response curves. These models provide rough, but plausible, estimates of the upper limits on lifetime risk. Slope factors and unit risks based on human epidemiological data are derived using conservative assumptions and, as such, they too are unlikely to underestimate risks for a given level of exposure.

USEPA assigns weight-of-evidence classifications to potential carcinogens. Under this system, chemicals are classified as either Group A, Group B1, Group B2, Group C, Group D, or Group E. These categories represent an assessment of the amount and quality of the data that support the finding that specific chemicals and elements can cause cancer in humans. Group A includes those substances for which high-quality studies have demonstrated a relationship between the exposure to the substance in question and the development of cancer in human populations. Groups B1, B2 and C represent chemicals with limited (B1) or insufficient (B2) human evidence of carcinogenicity; and sufficient (B1, B2) or insufficient (C) animal data. Group D substances are those for which there is insufficient or no evidence of carcinogenicity in humans or animals, while Group E substances are those for which no evidence of carcinogenicity is available in adequate human or animal studies.

3.4.1.2 Health Effects Criteria for Noncarcinogens

Oral health criteria for chemicals exhibiting noncarcinogenic effects are generally developed using verified reference doses (RfDs). These are developed by USEPA's RfD Work Group and listed in IRIS (USEPA, 1996), or can be obtained from HEAST (USEPA, 1995d) and supplements. The RfD is expressed in units of dose (mg chemical/kg body weight-day), and is usually derived either from human studies involving work-place exposures or from animal studies. The RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of the daily exposure to the human population (including sensitive subpopulations) that is likely to be without an appreciable risk of deleterious effects during a lifetime. The RfD is used as a reference point for gauging the potential effects of exposures. Usually, exposures (as chemical intakes or doses) that are less than the RfD are not likely to be associated with adverse health effects. As the frequency and/or magnitude of the exposures exceeding the RfD increase, the probability of adverse effects in a human population increases.

RfDs are developed for both chronic and subchronic exposures. Chronic RfDs are presented in IRIS or HEAST and are intended for use in evaluating exposures of durations greater than seven years. Subchronic RfDs are developed by USEPA's National Center for Environmental Assessment (NCEA, formerly called the Environmental Criteria and Assessment Office [ECAO]) and are used to characterize the potential for the occurrence of noncarcinogenic effects associated with short-term exposures (two weeks to seven years as defined by USEPA [1989a]). The subchronic RfDs are developed similarly to chronic RfDs, and are typically equal to chronic RfDs or are one order of magnitude greater (less stringent). The subchronic RfDs are presented in HEAST, but they are not peer reviewed.

The RfDs are derived using uncertainty factors that reflect scientific judgment regarding the various types of data used to estimate the RfD. RfDs are typically estimated from no-observable-adverse-effect-levels (NOAELs) or lowest-observable-adverse-effect-levels (LOAELs) in human or animal studies. Uncertainty factors, generally 10-fold factors, are intended to account for:

- the variation in sensitivity among members of the human population;
- the uncertainty in extrapolating animal data to the case of humans;
- the uncertainty in extrapolating from data obtained in a study that is less-than-lifetime exposure;
- the uncertainty in using LOAEL data, when necessary, rather than NOAEL data; and
- the inability of any single study to adequately address all possible adverse outcomes in humans.

To derive RfDs, NOAELs or LOAELs are divided by one or more uncertainty factors, as appropriate. When taken together, these uncertainty factors may confer an extra margin of safety of up to a factor of 10,000 below a LOAEL. In some cases, modifying factors are also applied to RfDs to take into account other uncertainties in the toxicity database and reflect the professional judgment of those reviewing the database. The net result is that RfDs are generally considered to provide a conservative estimate of the likelihood of adverse noncarcinogenic effects.

3.4.2 Health Criteria for Individual Chemicals of Potential Concern

Table 3-33 presents the oral human health effects criteria used to quantitatively evaluate potential health effects of human exposures to COPCs at OU3. Consistent with USEPA (1989a), subchronic toxicity criteria should be used to evaluate substantially less-than-lifetime exposures. As a result, chronic toxicity criteria were used to evaluate exposure pathways for all receptors except construction/excavation workers. Because construction/excavation workers at the ditches would be expected to work at OU3 for no more than one year, subchronic toxicity criteria were used for this receptor. Subchronic RfDs for all chemicals for this pathway were the same as the chronic RfDs, and are thus not presented separately.

Mercury was selected as a COPCs in fish, and because the most likely form of mercury in fish tissue would be in the methylated form, the toxicity criterion for methyl mercury was used to assess potential effects associated with ingestion of mercury in fish.

USEPA-approved oral health effects criteria were not available for delta-BHC, which was identified as a COPCs in fish. Oral toxicity criteria exist for other BHC congeners (e.g., alpha-, beta- and gamma-BHC), although none has the same Class D weight-of-classification as delta-BHC (i.e., the other BHC congeners are Class B2 or C carcinogens). Therefore, no other BHC congener was used as a surrogate to evaluate potential ingestion risks. The uncertainties associated with not evaluating delta-BHC are discussed in the Uncertainty Section.

Toxicity criteria have not been developed by USEPA specifically for the dermal route of exposure; instead, oral health effects criteria are adjusted to assess this pathway. In order to have a meaningful comparison between the dermal dose estimates, which represent internal (or absorbed) doses, and toxicity criteria, which typically represent potential (or administered) doses, toxicity criteria should be modified to represent absorbed doses. (In cases where the toxicity criteria are based on internal doses, this modification is not required.) The method for modifying toxicity criteria involves determination of an absolute oral absorption factor for each chemical and use of this value to increase the chemical's cancer slope factor or decrease the chemical's RfD. Cancer slope factors and RfDs adjusted in this manner are then more appropriate to assess absorbed dose-response, rather than administered dose-response. The absolute oral absorption factors that are applied should reflect the specific conditions under which the toxicological study was conducted (e.g., method of administration such as gavage, water or diet, and vehicle of administration such as solvent or solution). Table 3-34 presents the absolute oral absorption factors used to adjust the oral toxicity criteria for the chemicals of concern when evaluating dermal absorption of chemicals, as well as the actual adjusted toxicity criteria. For most chemicals, absolute oral absorption factors were obtained from the Agency for Toxic Substances and Disease Registry (ATSDR) Toxicological Profile documents. For those chemicals for which sufficient information is lacking, a default absolute oral absorption factor of one (1.0) was used (i.e., oral toxicity criteria were not changed).

3.5 RISK CHARACTERIZATION

This section of the HHRA evaluates the potential human health effects associated with exposures to chemicals in sediment, surface water, and fish at OU3. To quantitatively assess risks associated with exposures to chemicals at the site, the health effects criteria (slope factors/RfDs) presented in the toxicity assessment (Section 3.4) were combined with the average daily doses ([L]ADDs) derived in the exposure assessment (Section 3.3).

For oral exposures to potential carcinogens, excess lifetime cancer risks were obtained by multiplying the estimated LADDs for each chemical by its upper-bound cancer slope factor. The total upper-bound excess lifetime cancer risk for each pathway was obtained by summing the chemical-specific risk estimates. This approach is consistent with USEPA's guidelines for evaluating the toxic effects of chemical mixtures (USEPA, 1989a). Using this approach, a risk level of 1×10^{-6}, for example, represents an upper-bound probability of one in one million that an individual could contract cancer due to exposure to the potential carcinogen under the specified exposure conditions.

The approach of calculating carcinogenic risks by multiplying the LADD by the slope factor assumes that the increased risk of cancer resulting from exposure to a constituent is linearly proportional to the amount of chemical intake averaged over a lifetime. According to USEPA (1989a) HHRA guidance, this approach is only appropriate when the estimated carcinogenic risks calculated are less than 10^{-2} (i.e., one excess cancer case per 100 people exposed). If the estimated risks are above 10^{-2}, the assumption of linearity is not valid. In such cases, the carcinogenic risks should be calculated using the following equation, per USEPA HHRA guidance (USEPA, 1989a).

$$Risk = 1 - e^{(-LADD*CSF)}$$

For those chemicals resulting in risks greater than 1×10^{-2}, the potential carcinogenic risks were estimated by summing the chemical-specific risks to yield exposure pathways risks. Implicit in this approach is the assumption that potential carcinogenic risks from multiple chemical exposures are additive such that the total pathway-specific risk is equal to the sum of the individual chemical-specific

risks. Similarly, the excess lifetime cancer risks for each carcinogenic compound were also summed for each exposure pathway. The resulting total chemical-specific risks represent the upper-bound potential risk of developing cancer from that chemical upon exposure to that medium (i.e., the risk may be lower, but is unlikely to be greater).

The upper-bound lifetime excess cancer risks derived in this report can be compared to USEPA's risk range for health protectiveness at Superfund sites of 1×10^{-6} to 1×10^{-4} (USEPA, 1990b). In addition, USEPA's Office of Solid Waste and Emergency Response (USEPA, 1991b) has issued a directive clarifying the role of the HHRA in the Superfund process. The directive states that where the cumulative carcinogenic site risk to an individual based on reasonable maximum exposure for current or future land-use for all media combined is less than 1×10^{-4}, and the non-carcinogenic hazard quotient is less than one, action generally is not warranted unless there could be adverse environmental effects.

Potential adverse effects associated with oral and dermal exposures to noncarcinogens are presented as the ratio of the ADD to the reference dose (ADD:RfD). Values of these ratios, called hazard quotients, that are greater than one are indicative of a potential for adverse health effects. The additive effect for each noncarcinogen is assumed, and the sum of the hazard quotients for all the individual COPCs in a given pathway is termed the hazard index. The hazard index is useful as a reference point for gauging the potential effects of environmental exposures to complex mixtures. Hazard indices that are less than 1.0 should be viewed as indicating, with a high level of assurance, but not complete certainty, that adverse effects would not be associated with the exposures being evaluated. Hazard indices exceeding 1.0 indicate the potential for the occurrence of adverse effects. A decision should not be categorically drawn that hazard indices less than one are acceptable (or risk-free) or that hazard indices greater than one are unacceptable (or will result in adverse effects). This is a consequence of the great uncertainty inherent in estimates of the ADD:RfD ratio, in addition to the fact that there are uncertainties associated with assuming the individual hazard quotients in the hazard index calculation are additive.

In cases where the calculated hazard index exceeds one, the COPCs are subdivided into categories based on target organ or critical effect (e.g., liver, kidney, etc.), in accordance with USEPA guidance (USEPA, 1989a). Hazard indices are then recalculated for these categories to identify the potential for noncarcinogenic effects to occur with respect to any given endpoint. Organ-specific hazard indices exceeding 1.0 indicate the potential for the occurrence of adverse effects. They do not, however, provide a numerical estimate of either the probability or severity of the adverse effect.

The following sections present the predicted risks and hazard indices associated with each exposure pathway evaluated in the HHRA. Sections 3.5.1 and 3.5.2 present the estimated risks for individual pathways for the current and future exposure scenarios, respectively. Section 3.5.3 presents the cumulative risk estimates for all exposure pathways evaluated under both current and future land-use conditions.

3.5.1 Potential Risks Under Current Land-Use Conditions

3.5.1.1 Sediment

As shown in Tables 3-35 and 3-36, excess lifetime cancer risks associated with trespasser/recreational user ingestion and dermal exposures to chemicals in sediment from the PCBs Area were 7×10^{-7} and 2×10^{-6}, respectively, both due to PCB-1260 exposures. Because none of the COPCs at the PCBs Area had RfDs, hazard indices were not calculated. Excess lifetime cancer risks associated with ingestion and dermal exposures to chemicals in sediment from the Pesticides Area were 3×10^{-8} and 2×10^{-7}, respectively. Once again, because none of the COPCs at the Pesticides Area had RfDs, hazard indices were not calculated.

3.5.1.2 Surface Water

As shown in Table 3-37, the hazard index associated with trespasser/recreational user dermal exposures to chemicals in surface water from both the PCBs and Pesticides Areas were much lower than one, indicating that noncarcinogenic adverse effects would not likely occur. Because no carcinogenic chemicals were selected as COPCs for either area, excess lifetime cancer risks were not calculated.

3.5.1.3 Surface Soil

As shown in Tables 3-38 and 3-39, excess lifetime cancer risks associated with trespasser/recreational user ingestion and dermal exposures to chemicals in soil from the PCBs Area were 3×10^{-6} and 2×10^{-5}, respectively, both due to exposures to benzo(a)pyrene. Because none of the COPCs had RfDs, hazard indices were not calculated.

3.5.2 Potential Risks Under Future Land-Use Conditions

3.5.2.1 Sediment

As shown in Tables 3-40 and 3-41, excess lifetime cancer risks associated with a child's ingestion and dermal exposures to chemicals in sediment from the PCBs Area were 5×10^{-6} and 4×10^{-6}, both due to PCB-1260. Because none of the COPCs had RfDs, hazard indices were not calculated. Excess lifetime cancer risks associated with ingestion and dermal exposures to chemicals in sediment from the Pesticides Area were 2×10^{-7} and 3×10^{-7}, respectively. Once again, because none of the COPCs had RfDs, hazard indices were not calculated.

As shown in Tables 3-42 and 3-43, excess lifetime cancer risks associated with worker ingestion and dermal exposures to chemicals in sediment from the PCBs Area were 2×10^{-7} and 1×10^{-7}. Because no noncarcinogenic chemicals were selected as COPCs, hazard indices were not calculated for the PCBs Area. Excess lifetime cancer risks associated with ingestion and dermal exposures to chemicals in sediment from the Pesticides Area were 1×10^{-8} and 8×10^{-9}, respectively. Once again, because no noncarcinogenic chemicals were selected as COPCs, hazard indices were not calculated.

As shown in Tables 3-44 and 3-45, excess lifetime cancer risks associated with an environmental educator's ingestion and dermal exposures to chemicals in sediment from the PCBs Area were 6×10^{-6} and 1×10^{-5}. Because no noncarcinogenic chemicals were selected as COPCs, hazard indices were not calculated for the PCBs Area. Excess lifetime cancer risks associated with ingestion and dermal exposures to chemicals in sediment from the Pesticides Area were 3×10^{-7} and 1×10^{-6}, respectively. Once again, because no noncarcinogenic chemicals were selected as COPCs, hazard indices were not calculated.

3.5.2.2 Surface Water

As shown in Table 3-46, the hazard indices associated with a child's dermal exposures to chemicals in surface water from both the PCBs and Pesticides Areas were much lower than one, indicating that noncarcinogenic adverse effects would not likely occur. Because no carcinogenic chemicals were selected as COPCs for either area, excess lifetime cancer risks were not calculated.

As shown in Table 3-47, the hazard indices associated with an environmental educator's dermal exposures to chemicals in surface water from both the PCBs and Pesticides Areas were much lower than one, indicating that noncarcinogenic adverse effects would not likely occur. Because no carcinogenic chemicals were selected as COPCs for either area, excess lifetime cancer risks were not calculated.

3.5.2.3 Fish

As shown in Table 3-48, under future land-use conditions, excess lifetime cancer risks associated with ingestion of fish ranged from 5×10^{-3} for eel to 2×10^{-5} for white perch. Without exception, the greatest risks for all fish species were due to PCB-1260 in fish tissue. Hazard indices for all species were less than one, indicating that ingestion of fish would not result in adverse effects due to noncarcinogenic compounds.

3.5.2.4 Groundwater

As shown in Tables 3-49 and 3-50, excess lifetime cancer risks associated with child and adult ingestion and dermal absorption of COPCs in groundwater were all below the $1x10^{-6}$ level. Hazard indices for ingestion of groundwater were above one, due to iron (for which no target organ exists) and manganese (affecting the CNS), indicating that adverse effects could occur to the CNS for both child and adult residents. Hazard indices associated with the dermal pathway were below one.

As shown in Table 3-51, the excess lifetime cancer risk associated with worker ingestion of COPCs in groundwater was $2x10^{-7}$, while the hazard index was below one, indicating noncarcinogenic effects would not likely occur.

3.5.2.5 Surface Soil

As shown in Tables 3-52 and 3-53, excess lifetime cancer risks associated with child ingestion and dermal exposures to chemicals in soil from the PCBs Area were 9×10^{-5}. Risks for adults were 5×10^{-5} and 2×10^{-4}, respectively, both due to exposures to benzo(a)pyrene. Because none of the COPCs had RfDs, hazard indices were not calculated.

As shown in Tables 3-54 and 3-55, excess lifetime cancer risks associated with worker ingestion and dermal exposures to chemicals in soil from the PCBs Area were 1×10^{-5} and 1×10^{-4}, respectively, both due to exposures to benzo(a)pyrene. Because none of the COPCs had RfDs, hazard indices were not calculated.

As shown in Tables 3-56 and 3-57, excess lifetime cancer risks associated with an environmental educator's ingestion and dermal exposures to chemicals in soil from the PCBs Area were 3×10^{-5} and 1×10^{-4}, respectively, both due to exposures to benzo(a)pyrene. Because none of the COPCs had RfDs, hazard indices were not calculated.

3.5.3 Cumulative Risks

Individuals may be exposed at one time by a combination of pathways, and therefore, the combined pathway risks for plausible multiple pathway exposures were calculated. Cumulative risk estimates calculated for trespassers/recreational users under current land-use conditions are first presented, and are followed by cumulative risk estimates for workers, environmental educators, and child and adult residents under future land-use conditions.

3.5.3.1 Current Land-Use Conditions

The summary of cumulative risks for trespassers/recreational users under current land-use conditions are presented in Table 3-58. Cumulative risks for exposures to the PCBs Areas and Pesticides Areas were calculated separately.

As shown in Table 3-58, the cumulative risks for trespassers/recreational users was 3×10^{-5} for the PCBs Area and 2×10^{-7} at the Pesticides Area, which are either lower than or in the mid range of the 1×10^{-6} to 1×10^{-4} risk range for health protectiveness at Superfund sites. The cumulative hazard index was below one at both areas, indicating that adverse noncarcinogenic effects would not be likely to occur, based on exposures through all pathways.

3.5.3.2 Future Land-Use Conditions

Summaries of cumulative risks for hypothetical future workers, environmental educators, and child and adult residents are also presented in Table 3-58. Once again, cumulative risks were calculated separately for both the PCBs and the Pesticides Areas.

As shown in Table 3-58, the cumulative risk for workers was 1×10^{-4} for the PCBs Area and 2×10^{-8} for the Pesticides Area, either lower than or at the high end of the 1×10^{-6} to 1×10^{-4} risk range.

The cumulative risk for future environmental educators was 1×10^{-4} for the PCBs Area and 1×10^{-6} for the Pesticides Area, either at the low or high end of the 1×10^{-6} to 1×10^{-4} risk range for health protectiveness at Superfund sites. The cumulative hazard index was below one at both areas, indicating that adverse noncarcinogenic effects would not be likely to occur, based on exposures through all pathways.

The cumulative risk for child residents was 2×10^{-4} for the PCBs Area and 5×10^{-7} for the Pesticides Area, either lower than or just above the 1×10^{-6} to 1×10^{-4} risk range, as shown in Table 3-58. The cumulative hazard index was above one (5) for the PCBs Area, while the cumulative hazard index was below one for the Pesticides Area.

The cumulative risk for adult residents was 5×10^{-3}, above the 1×10^{-6} to 1×10^{-4} risk range, as shown in Table 3-58. The cumulative hazard index for adults was above one (2).

3.6 UNCERTAINTY ANALYSIS

There is a large degree of uncertainty associated with the estimates of human health risks in any HHRA. Consequently, the estimates calculated for OU3 should not be construed as absolute estimates of risk but rather as conditional estimates based on a number of assumptions regarding exposure and toxicity. In general, the primary sources of uncertainty are associated with environmental sampling and analysis; selection of chemicals for evaluation; exposure assessment; and toxicological data.

A thorough understanding of the uncertainties associated with the risk estimates is critical to understanding the true nature of the estimated risks and to placing the estimated risks in proper perspective. Some of the more important sources of uncertainty associated with the estimations of risk at OU3 are summarized below.

3.6.1 Environmental Sampling and Analysis

Uncertainty in environmental chemical analysis can stem from several sources including errors inherent in the sampling or analytical methods. Analytical precision or accuracy errors can be the source of a great deal of uncertainty. There is uncertainty associated with chemicals reported in samples at concentrations below the reported detection limit, but still included in data analysis, and with those chemicals qualified with the letter J, indicating that the concentrations are estimated. The effects of using data with these uncertainties may over- or under-estimate risks.

As noted earlier, surface water sampling occurred during or after storm events, so it is possible that inorganics surface water concentrations were higher than they would have been if no storm events had occurred prior to sampling. The elevated suspended solids concentrations likely resulted in retaining several inorganic COPCs for evaluation, whereas they may not have been selected if suspended sediment concentrations would have been lower.

3.6.2 Selection of Chemicals for Evaluation

A comparison of maximum detected chemical concentrations to USEPA Region III RBCs was conducted for each medium. Chemicals whose maximum concentrations were below their respective RBCs were not carried through the assessment. It is unlikely that this risk-based screening would have excluded chemicals that would be of concern, based on the conservative exposure assumptions and conservatively derived toxicity criteria that are the basis of the RBCs. Although following this methodology does not provide a quantitative risk estimate for all chemicals, it focuses the assessment on the chemicals accounting for the greatest risks (i.e., chemicals whose maximum concentrations exceeded their respective RBCs), and the overall cumulative risk estimates would not be expected to be significantly (if at all) greater.

There is uncertainty associated with eliminating inorganic chemicals from evaluation based on comparisons of site and background data. Although five samples were available in the background data set for both sediment and surface water, there nevertheless exists some uncertainty associated with the inorganic chemical selection process if the background samples do not adequately characterize true background concentrations. Therefore, in accordance with USEPA Region III policy, an evaluation was conducted for chemicals that were determined to be within background concentrations, but that exceeded their respective RBCs. Risk estimates for all chemicals that were classified as "b" (within background levels but above respective RBCs) in the data summary tables were calculated. Risks for all chemicals and pathways were typically below or in the low-to-mid range of the USEPA target risk range of $1x10^{-6}$ to $1x10^{-4}$; all hazard indices were less than one, indicating that noncarcinogenic effects are not likely. Consequently, eliminating chemicals as COPCs that were within background concentrations and greater than RBCs did not significantly alter the conclusions concerning risks associated with exposures to site-related inorganic concentrations.

3.6.3 Exposure Assessment

There are several sources of uncertainty in the exposure assessment, including the determination of the exposure point concentrations, the selection of input parameters used to estimate

chemical intakes ([L]ADDs), and other assumptions used in the exposure models. The uncertainties associated with these various sources are discussed below.

Only unfiltered (i.e., total) surface water exposure point concentrations were available for evaluating dermal absorption of chemicals in surface water, even though chemicals in the dissolved phase would more readily be dermally absorbed than chemicals in the particulate phase. However, because only unfiltered concentrations were available, they were conservatively used to evaluate this pathway, therefore, most likely overestimating potential exposures to COPCs in surface water.

When calculating exposure point concentrations in sediment from sampling data, ½ of the reported detection limit was used for non-detected concentrations in the calculation of the 95% UCL. Any approach dealing with non-detected chemical concentrations is associated with some uncertainty. This is because chemicals that were not detected at the specified detection limit may be absent from the medium or may be present at any concentration below the detection limit. This uncertainty will err on the side of overestimation of exposure point concentrations as the number of non-detects in a data set increases.

The 95% UCL was used preferably as the exposure point concentration for each medium. If the 95% UCL exceeded the maximum detected value, the maximum was conservatively used as a default for the exposure point concentration. Using a value that is based on one sampling location (i.e., the maximum) is associated with some uncertainty, and adds a great deal of conservatism to the assessment. Maximum detected values were used as exposure point concentrations for all organic COPCs in sediment from the PCBs and Pesticides Areas, three of the six inorganics selected as COPCs in surface water from two areas, and over half of the COPCs selected from groundwater and surface soil. A large number of exposure point concentrations of COPCs in fish also were the maximum detected concentrations.

With respect to determining exposure point concentrations, it was assumed that the concentrations of chemicals in the media evaluated would remain constant over time. Depending on the properties of the chemicals and the media in which they were detected, this assumption could overestimate risks to a low or high degree, since it is possible that chemicals could degrade or be transported to other media. It should be noted that the sources of PCBs (i.e., the washrack and the oil/water separator) have been removed. Therefore, concentrations of PCBs in sediment will not increase over time, but will likely decrease.

An underlying assumption of the HHRA is that individuals in the site would engage in certain activities that would result in exposures via each selected pathway. However, it should be noted that even if an individual engaged in an activity, it is not necessarily true that an exposure would be experienced. For example, it is unlikely that every time a trespasser comes on the site, he or she would contact and incidentally ingest and be dermally exposed sediment. More unlikely, however, are the assumptions that residential development would occur at OU3, especially in light of the transfer of the property to the USFWS. Further, making the assumption that hypothetical future residents would consume fish (especially eel) from the ditches at OU3 is also considered to be extremely unlikely. If individuals were to reside in the vicinity of OU3, they would more likely catch and eat fish from Occoquan Bay than from the ditches. Further, the fish ingestion rate that was used to evaluate adult ingestion of fish was based on recreational fishing and is equivalent to about one 8-ounce servings per week (USEPA, 1991a), much higher than any likely fish ingestion scenario that would occur at OU3.

The parameter values used to describe the extent, frequency, and duration of exposure are associated with some uncertainty. Actual risks for certain individuals within an exposed population may vary from those predicted depending upon their actual intake rates (e.g., sediment ingestion rates), nutritional status, or body weights. The exposure assumptions were selected to produce an upper-bound estimate of exposure in accordance with USEPA guidelines regarding evaluation of potential exposures at Superfund sites (e.g., exposures were assumed to occur for 30 years for adult residents). In addition, many USEPA (1989a) default exposure parameters are highly conservative and are based on risk management interpretations of limited data. An example is soil ingestion rates, which were used to evaluate sediment ingestion exposures. Although current USEPA guidance recommends default soil ingestion rates of 100 mg/day for those over six years of age, other studies, such as Calabrese et al. (1990), have shown that the USEPA default soil ingestion rate of 100 mg/day is likely to greatly

overestimate exposures and risks. In addition, all chemicals in sediment were assumed to be 100% bioavailable; this assumes that all ingested chemicals present in a sediment matrix are absorbed through the gastrointestinal tract, which is unlikely due to their affinity to the sediment particles. Therefore, based on the conservative exposure assumptions used in the HHRA, exposures and estimated potential risks are likely to be overestimated for the exposure pathways.

Evaluation of the dermal exposure pathway is affected by uncertainties in exposure parameters specific to dermal contact. For example, there is uncertainty associated with the exposed skin surface areas used, since the choice of exposed body parts could slightly over- or underestimate risks. More significant uncertainties are associated with the selection and use of dermal absorption fractions. Very limited information is available on dermal absorption of chemicals from contacted sediment under realistic environmental conditions. In fact, there are no actual human epidemiological data to support the hypothesis that absorption of sediment-bound compounds under realistic exposure conditions is a complete route of exposure. Therefore, evaluation of dermal absorption of COPCs from sediment may result in an overestimation of risks.

3.6.4 Toxicological Data

In most HHRAs, one of the largest sources of uncertainty is health criteria values. The health criteria used to evaluate long-term exposures, such as reference doses or cancer slope factors, are based on concepts and assumptions that bias an evaluation in the direction of over-estimation of health risk. As USEPA notes in its Guidelines for Carcinogenic RA (USEPA, 1986a):

> "There are major uncertainties in extrapolating both from animals to humans and from high to low doses. There are important species differences in uptake, metabolism, and organ distribution of carcinogens, as well as species and strain differences in target site susceptibility. Human populations are variable with respect to genetic constitution, diet, occupational and home environment, activity patterns, and other cultural factors."

These uncertainties are compensated for by using upper-bound 95% UCLs or maximum likelihood estimates for cancer slope factors for carcinogens, and safety factors for reference doses for noncarcinogens. The assumptions provide a rough but plausible estimate of the upper limit of risk.

For dermal exposure pathways, the absence of dermal toxicity criteria necessitated the use of oral toxicity data. To calculate risk estimates for the dermal pathway, therefore, absorbed dermal doses were combined with oral toxicity values. As described in Section 3.4, oral toxicity values, which are typically expressed in terms of potential (or administered) doses, should be adjusted when assessing dermal doses, which are expressed as internal (or absorbed) doses. In this assessment, absolute oral absorption factors that reflect the toxicity study conditions were used to modify the oral toxicity criteria. For those chemicals for which sufficient information is lacking, a default oral absorption factor of 100% (1.0) was used. The risk estimates for the dermal pathways may be under-estimated depending on how closely these values reflect the difference between the oral and dermal routes. It should be noted that the risks associated with dermal exposure to beryllium are especially affected by the very low absolute oral absorption factor (i.e., 0.5%). Considering that beryllium is assumed to be absorbed more efficiently through the skin (1%) than in the gastrointestinal system (0.5%), considerable uncertainty appears to be associated with the absorption efficiency of beryllium.

Delta-BHC could not be quantitatively evaluated because no toxicity criteria exist for this compound. Although oral toxicity criteria exist for other BHC congeners (e.g., alpha-, beta- and gamma-BHC), although none has the same Class D weight-of-classification as delta-BHC (i.e., the other BHC congeners are Class B2 and C carcinogens). Therefore, no other BHC congener was used as a surrogate to evaluate potential ingestion risks. Although not quantifying risks for delta-BHC could underestimate fish ingestion risks, risks would not likely be significantly underestimated, because chemicals that drove risks for the fish ingestion pathway were detected at much greater concentrations.

3.7 SUMMARY AND CONCLUSIONS

This HHRA was performed to evaluate the potential human health effects associated with chemical contamination at OU3. The first task of the HHRA was to summarize chemicals found in

sediment, surface water, fish, groundwater, surface soil, and subsurface soil at OU3. The data from sediment and surface water were then separated into groupings, according to areas of contamination.

After the data were summarized, maximum concentrations of detected chemicals were compared to USEPA Region III RBCs. If the chemical concentrations exceeded the RBCs, they were retained as COPCs. The next step in the screening process was to statistically compare on-site and background chemical concentrations for inorganic chemicals that were not screened out in the RBC screening. If inorganic chemical concentrations were within background levels, they were not considered to be COPCs. Risks for these inorganic chemicals present at concentrations greater than RBCs but within background levels also were evaluated, although separately from site-related COPCs. Chemicals that were not eliminated as a result of both the RBC and background screening procedures were considered to be COPCs, and were retained for detailed evaluation in the HHRA.

For each COPC, quantitative oral toxicity criteria were compiled. The toxicity criteria were obtained primarily from USEPA's IRIS and HEAST.

Potential exposure pathways were reviewed, and the following complete exposure pathways were evaluated for current land-use conditions:

- Incidental ingestion and dermal absorption of COPCs in sediment by a trespasser/recreational user;
- Dermal absorption of COPCs in surface water by a trespasser/recreational user; and
- Incidental ingestion and dermal absorption of COPCs in surface soil by a trespasser/ recreational user.

Although the likelihood of future residential exposures is highly unlikely, since the facility will be transferred to the USFWS, under future land-use conditions, the following complete exposure pathways were quantitatively evaluated:

- Incidental ingestion and dermal absorption of COPCs in sediment by child residents;
- Dermal absorption of COPCs in surface water by child residents;
- Incidental ingestion and dermal absorption of COPCs in sediment by workers;
- Incidental ingestion and dermal absorption of COPCs in sediment by environmental educators;
- Dermal absorption of COPCs in surface water by environmental educators;
- Ingestion of fish by adult residents;
- Incidental ingestion and dermal absorption of COPCs in surface soil by child residents;
- Incidental ingestion and dermal absorption of COPCs in surface soil by adult residents;
- Incidental ingestion and dermal absorption of COPCs in surface soil by workers;
- Incidental ingestion and dermal absorption of COPCs in surface soil by environmental educators;
- Ingestion and dermal absorption of COPCs in groundwater by child residents;
- Ingestion and dermal absorption of COPCs groundwater by adult residents; and
- Ingestion of COPCs in groundwater by workers.

An RME case was evaluated in this HHRA, in order to place a conservative upper-bound on the potential risks, meaning that the risk estimates were unlikely to be underestimated but may very well have been overestimated. ADDs for noncarcinogenic effects and LADDs for carcinogenic effects were estimated using exposure point concentrations and assumptions to characterize human exposure to COPCs from the site via oral and dermal pathways. ADDs/LADDs were then compared to relevant toxicity criteria to calculate risks associated with the evaluated exposures. The resulting risk estimates

were the upper-bound excess lifetime cancer risks for carcinogenic chemicals and hazard indices for noncarcinogenic chemicals. Using the risk or hazard index values, risks and potential adverse effects from exposure to site-related chemicals were assessed. Cancer risk estimates were compared to USEPA's target risk range for health protectiveness at Superfund sites of $1x10^{-6}$ to $1x10^{-4}$, as recommended by USEPA (1990b). The potential for adverse noncarcinogenic effects was assessed by comparing the noncarcinogenic hazard indices to a value of one; a hazard index less than one indicates that adverse noncarcinogenic health effects would not be expected to occur. The following sections summarize the cumulative risk results of the quantitative HHRA.

3.7.1 Current Land-Use

The cumulative risks for trespassers/recreational users was 3×10^{-5} for the PCBs Area and 2×10^{-7} at the Pesticides Area, which are either lower than or in the mid range of the 1×10^{-6} to 1×10^{-4} risk range for health protectiveness at Superfund sites. The cumulative hazard index was below one at both areas, indicating that adverse noncarcinogenic effects would not be likely to occur, based on exposures through all pathways.

3.7.2 Future Land-Use

The cumulative risk for workers was 1×10^{-4} for the PCBs Area and 2×10^{-8} for the Pesticides Area, either lower than or at the high end of the 1×10^{-6} to 1×10^{-4} risk range.

The cumulative risk for future environmental educators were 1×10^{-4} for the PCBs Area and 1×10^{-6} for the Pesticides Area, either at the low or high end of the 1×10^{-6} to 1×10^{-4} risk range for health protectiveness at Superfund sites. The cumulative hazard index was below one at both areas, indicating that adverse noncarcinogenic effects would not be likely to occur, based on exposures through all pathways.

The cumulative risk for child residents was 2×10^{-4} for the PCBs Area and 5×10^{-7} for the Pesticides Area, either lower than or just above the 1×10^{-6} to 1×10^{-4} risk range. The cumulative hazard index was above one (5) for the PCBs Area, while the cumulative hazard index was below one for the Pesticides Area.

The cumulative risk for adult residents was 5×10^{-3}, above the 1×10^{-6} to 1×10^{-4} risk range. The cumulative hazard index for adults was above one (2).

3.7.3 Overall Risks at Operable Unit Three

The most significant risks associated with exposures to evaluated media at OU3 are associated with ingestion of fish by hypothetical future residents. Even though elevated risks were calculated for this receptor, however, it should be noted that this pathway is considered to be highly unlikely for several reasons. First, residents would not likely reside at WRF, since the facility will be transferred to the USFWS. Second, individuals would not likely fish at OU3 ditches, since there are other areas at WRF with much better fishing (e.g., Belmont and Occoquan Bays, Marumsco Creek, and the pond at WRF). Finally, the ditches do not support great quantities or sizes of fish to allow for significant ingestion exposures. In addition, the species associated with the greatest risks (i.e., eel) is not a species that would likely be consumed at all.

Risks associated with exposures to COPCs in sediment and surface water were within or below the 1×10^{-6} to 1×10^{-4} risk range for all receptors and both areas, while all noncancer hazard indices were lower than one, indicating the noncarcinogenic adverse effects would not be likely to occur. Risks associated with exposures to groundwater were within the target risk range, but the hazard indices were above one (due to two inorganics). Finally, risks associated with exposures to soil were elevated for most receptors (due to benzo[a]pyrene).

TABLE 3-1
REGION III RISK-BASED CONCENTRATIONS (RBCs)
FOR DETECTED CHEMICALS AT OU3

Chemical	RBC Value (a)
Residential Soil (mg/kg)	
Organics:	
Acenaphthene	470
Anthracene	2,300
Benzo(a)anthracene	0.88
Benzo(a)pyrene	0.088
Benzo(b)fluoranthene	0.88
Benzo(g,h,i)perylene	230(b)
Benzo(k)fluoranthene	8.8
Benzoic Acid	31,000
Chlordane (total)	0.49
alpha-Chlordane	0.49(c)
gamma-Chlordane	0.49(c)
Chrysene	88
DDD	2.7
DDE	1.9
DDT	1.9
Dibenzo(a,h)anthracene	0.088
Dibenzofuran	31
bis(2-Ethylhexyl)phthalate	46
Fluoranthene	310
Fluorene	310
Indeno(1,2,3-c,d)pyrene	0.88
1-Methylnaphthalene	230(b)
2-Methylnaphthalene	230(b)
Naphthalene	310
PCB-1260	0.083(d)
Phenanthrene	230(b)
Pyrene	230
Inorganics:	
Aluminum	7,800
Arsenic	0.43
Barium	550
Beryllium	0.15
Calcium	4,000,000(e)
Chromium	39(f)
Cobalt	470
Copper	310
Iron	2,300
Lead	400(g)
Magnesium	800,000(e)
Manganese	156
Nickel	160
Potassium	1,000,000(e)
Selenium	39
Sodium	1,000,000(e)
Vanadium	55
Zinc	2,300
Tap Water (ug/L)	
Organics:	
Acenaphthylene	110

TABLE 3-1
REGION III RISK-BASED CONCENTRATIONS (RBCs)
FOR DETECTED CHEMICALS AT OU3

Chemical	RBC Value (a)
Acetone	370
Anthracene	1,100
Dieldrin	0.0042
Endosulfan sulfate	22
Fluoranthene	150
Phenanthrene	110
Pyrene	110
Inorganics:	
Aluminum	3,700
Arsenic	0.045
Barium	260
Cadmium	1.8
Calcium	400,000(e)
Chromium	18(f)
Copper	150
Iron	1,100
Lead	15(g)
Magnesium	80,500(e)
Manganese	88
Potassium	100,000(e)
Selenium	18
Silver	18
Sodium	100,000(e)
Thallium	0.29(h)
Vanadium	26
Zinc	1,100
Fish (mg/kg)	
Organics:	
delta BHC	0.0000005(i)
alpha-Chlordane	0.0000024(c)
gamma-Chlordane	0.0000024(c)
DDD	0.000013
DDE	0.0000093
Methoxychlor	0.00068
PCB-1260	0.00000041(d)
Inorganics:	
Mercury	0.041(l)
Industrial Soil (mg/kg)	
Organics:	
PCB-1260	.74 (d)
Inorganics:	
Aluminum	100,000
Barium	14,000
Beryllium	1.3
Calcium	4,000,000(e)
Chromium	1000(f)
Cobalt	12,000
Copper	8,200
Iron	61,000
Lead	400(g)

TABLE 3-1
REGION III RISK-BASED CONCENTRATIONS (RBCs)
FOR DETECTED CHEMICALS AT OU3

Chemical	RBC Value (a)
Magnesium	800,000(e)
Manganese	4,700
Nickel	4,100
Potassium	1,000,000(e)
Selenium	1,000
Sodium	1,000,000(e)
Vanadium	1,400
Zinc	61,000

(a) RBCs for noncarcinogenic chemicals are based on a hazard quotient of 0.1, following USEPA Region III guidance.
(b) The RBC for pyrene was used for noncarcinogenic polycyclic aromatic hydrocarbons (PAHs) lacking RBCs.
(c) The RBC for chlordane was used.
(d) The RBC for carcinogenic PCBs was used.
(e) Value is an allowable daily intake (ADI) level.
(f) The RBC for chromium VI was used.
(g) Because no RBC exists for lead, the residential soil screening level USEPA (1994b) was used for sediment and the action level USEPA (1990c) was used for surface water.
(h) The most conservative RBC for thallium salts was used.
(i) The RBC for alpha BHC was used.
(j) The RBC for endosulfan was used.
(l) The RBC for methyl mercury was used.

TABLE 3-2
SUMMARY OF CHEMICALS DETECTED IN OU3 SEDIMENT
PCBs AND PESTICIDES AREAS
(Concentrations in mg/kg)

Chemical	Frequency of Detection (a)	Arithmetic Mean (b)	Range of Detection Limits	Range of Detected Concentrations	Residential Soil RBC (c)	Maximum Detect > RBC?	Range of Background Concentrations (d)	Site > Background (e)
PCBs Area								
Organics:								
Acenaphthene	1 / 5	0.315	0.133	1.31	470	No	0.6683 - 0.919	---
Anthracene	5 / 5	0.0624	NU	0.0230 - 0.155	2,300	No	0.108 - 0.1685	---
Benzo(a)anthracene	3 / 4	0.163	0.0130	0.0220 - 0.591	0.88	No	0.0210 - 0.0310	---
* Benzo(a)pyrene	4 / 4	0.235	NU	0.0540 - 0.596	0.088	**Yes**	0.0290 - 0.0515	---
Benzo(b)fluoranthene	5 / 5	0.124	NU	0.00900 - 0.347	0.88	No	0.0610 - 0.0830	---
Benzo(g,h,i)perylene	2 / 5	0.0396	0.00700 - 0.168	0.0210 - 0.0560	230	No	0.0460 - 0.0800	---
Benzo(k)fluoranthene	3 / 4	0.0685	0.0180	0.0200 - 0.197	8.8	No	0.0170 - 0.0320	---
Benzoic Acid	1 / 5	0.299	0.1 - 0.3	1.0	31,000	No	ND	---
Chrysene	1 / 1	NC	NU	0.480	88	No	ND	---
DDD	1 / 5	0.00600	0.00300	0.0240	2.7	No	ND	---
Dibenzo(a,h)anthracene	1 / 5	0.0146	0.00300 - 0.0830	0.0120	0.088	No	0.0130 - 0.0220	---
Fluoranthene	4 / 4	0.286	NU	0.104 - 0.768	310	No	0.0550 - 0.0940	---
Fluorene	1 / 5	0.0758	0.0330	0.313	310	No	0.1568 - 0.355	---
Indeno(1,2,3-c,d)pyrene	2 / 5	0.0641	0.0030 - 0.0830	0.0340 - 0.227	0.88	No	0.0640 - 0.112	---
2-Methylnaphthalene	2 / 2	1.51	NU	1.24 - 1.78	230	No	ND	---
Naphthalene	3 / 5	0.794	0.133	0.380 - 2.90	310	No	0.351	---
* PCB-1260	5 / 5	2.26	NU	0.0430 - 6.04	0.083	**Yes**	ND	---
Phenanthrene	3 / 5	0.397	0.0330	0.356 - 0.915	230	No	ND	---
Pyrene	3 / 3	0.384	NU	0.0650 - 0.955	230	No	0.0530 - 0.130	---
Inorganics:								
b Aluminum	5 / 5	12,300	NU	8,980 - 15,900	7,800	**Yes**	10,500 - 15,200	No
Barium	5 / 5	143	NU	75.8 - 191	550	No	175	---
b Beryllium	5 / 5	1.44	NU	1.03 - 2.44	0.15	**Yes**	0.989 - 1.26	No
Calcium	4 / 4	1,890	NU	1,300 - 2,410	400,000	No	4,240 - 6,000	---
Chromium	5 / 5	17.9	NU	13.3 - 23.0	39	No	21.6 - 30.1	---
Cobalt	5 / 5	21.4	NU	8.50 - 36.1	470	No	14.6 - 20.7	---
Copper	5 / 5	19.8	NU	12.5 - 25.9	310	No	29.8 - 41.8	---
b Iron	5 / 5	16,500	NU	10,300 - 19,400	2,300	**Yes**	26,100 - 34,200	No
Lead	5 / 5	36.3	NU	20.9 - 50.6	400	No	22.775 - 42.2	---
Magnesium	5 / 5	1,420	NU	1,010 - 1,760	80,500	No	2,470 - 3,470	---
b Manganese	5 / 5	396	NU	216 - 564	190	**Yes**	911.5 - 1,690	No
Nickel	5 / 5	14.0	NU	7.72 - 19.1	160	No	19.3 - 30.0	---

TABLE 3-2
SUMMARY OF CHEMICALS DETECTED IN OU3 SEDIMENT
PCBs AND PESTICIDES AREAS
(Concentrations in mg/kg)

Chemical	Frequency of Detection (a)	Arithmetic Mean (b)	Range of Detection Limits	Range of Detected Concentrations	Residential Soil RBC (c)	Maximum Detect > RBC?	Range of Background Concentrations (d)	Site > Background (e)
Sodium	5 / 5	977	NU	565 - 1,240	100,000	No	932 - 1,710	---
b Vanadium	5 / 5	42.6	NU	28.9 - 57.9	55	**Yes**	35.5 - 52.5	No
Zinc	5 / 5	147	NU	63.2 - 257	2,300	No	114 - 157	---
Pesticides Area								
Organics:								
Anthracene	5 / 5	0.0922	NU	0.0280 - 0.190	2,300	No	0.108 - 0.1685	---
Benzo(a)anthracene	4 / 4	0.0288	NU	0.0130 - 0.0490	0.88	No	0.0210 - 0.0310	---
* Benzo(a)pyrene	5 / 5	0.0494	NU	0.0150 - 0.109	0.088	**Yes**	0.0290 - 0.0515	---
Benzo(b)fluoranthene	5 / 5	0.0640	NU	0.0200 - 0.120	0.88	No	0.0610 - 0.0830	---
Benzo(g,h,i)perylene	4 / 5	0.0505	0.00700	0.0280 - 0.0910	230	No	0.0460 - 0.0800	---
Benzo(k)fluoranthene	5 / 5	0.0312	NU	0.0100 - 0.0570	8.8	No	0.0170 - 0.0320	---
Benzoic Acid	1 / 5	0.788	0.140 - 0.700	3.10	31,000	No	ND	---
Chlordane	2 / 5	0.0668	0.0200	0.0410 - 0.263	0.49	No	ND	---
alpha-Chlordane	2 / 5	0.00830	0.00300	0.0160 - 0.021	0.49	No	ND	---
gamma-Chlordane	2 / 5	0.0113	0.00300	0.0220 - 0.0300	0.49	No	ND	---
DDD	1 / 5	0.00440	0.00300	0.0160	2.7	No	ND	---
Dibenzo(a,h)anthracene	2 / 5	0.00610	0.00300	0.0120 - 0.0140	0.088	No	0.0130 - 0.0220	---
Fluoranthene	5 / 5	0.0900	NU	0.0310 - 0.167	310	No	0.0550 - 0.0940	---
Fluorene	1 / 5	0.105	0.0330	0.459	310	No	0.1568 - 0.355	---
Indeno(1,2,3-c,d)pyrene	5 / 5	0.0352	NU	0.0120 - 0.0720	0.88	No	0.0640 - 0.112	---
Naphthalene	1 / 5	0.225	0.133	0.858	310	No	0.351	---
Pyrene	3 / 4	0.107	0.00700	0.0780 - 0.219	230	No	0.0530 - 0.130	---
Inorganics:								
b Aluminum	5 / 5	13,900	NU	10,600 - 15,600	7,800	**Yes**	10,500 - 15,200	No
Barium	5 / 5	138	NU	86.3 - 187	550	No	175	---
b Beryllium	5 / 5	1.22	NU	0.715 - 1.93	0.15	**Yes**	0.989 - 1.26	No
Calcium	4 / 4	1,890	NU	1,330 - 2,370	400,000	No	4,240 - 6,000	---
Chromium	5 / 5	19.5	NU	15.5 - 22.6	39	No	21.6 - 30.1	---
Cobalt	5 / 5	12.7	NU	8.19 - 19.1	470	No	14.6 - 20.7	---
Copper	5 / 5	18.9	NU	14.0 - 24.0	310	No	29.8 - 41.8	---
b Iron	5 / 5	22,200	NU	17,100 - 34,600	2,300	**Yes**	26,100 - 34,200	No
Lead	5 / 5	55.9	NU	36.4 - 84.5	400	No	22.775 - 42.2	---
Magnesium	4 / 4	1,560	NU	1,200 - 1,830	80,500	No	2,470 - 3,470	---
b Manganese	3 / 3	356	NU	315 - 391	190	**Yes**	911.5 - 1,690	No

TABLE 3-2
SUMMARY OF CHEMICALS DETECTED IN OU3 SEDIMENT
PCBs AND PESTICIDES AREAS
(Concentrations in mg/kg)

Chemical	Frequency of Detection (a)	Arithmetic Mean (b)	Range of Detection Limits	Range of Detected Concentrations	Residential Soil RBC (c)	Maximum Detect > RBC?	Range of Background Concentrations (d)	Site > Background (e)
Nickel	5 / 5	12.0	NU	8.0 - 15.2	160	No	19.3 - 30.0	---
Potassium	2 / 2	1,020	NU	991 - 1,040	100,000	No	1,450 - 2,120	---
Sodium	5 / 5	762	NU	599 - 944	100,000	No	932 - 1,710	---
b Vanadium	5 / 5	51.9	NU	44.1 - 68.8	55	**Yes**	35.5 - 52.5	No
Zinc	5 / 5	109	NU	57.6 - 194	2,300	No	114 - 157	---

(a) The number of samples in which the chemical was detected divided by the total number of samples analyzed.

(b) Calculated by averaging the detected concentration(s) with one-half the detection limit of non-detected sample(s).

(c) See Table 3-1 for a list of all residential soil RBCs. Calcium, magnesium, potassium, and sodium are essential nutrients and do not have RBCs. Maximum concentrations of these chemicals were compared to allowable daily intake (ADI) levels.

(d) Background concentrations were site-specific and are discussed in Section 2 of the FFS.

(e) Statistical comparisons to background were not performed on organics or on inorganic chemicals with a maximum concentration below respective RBCs or ADIs.

NC = Not calculated, since only one sample was available to calculate a mean concentration.

ND = Not Detected.

NU = Not used. The chemical was detected in all samples, thus detection limits were not used to calculate mean concentrations.

b = Chemical was detected at concentrations above its residential soil RBC or ADI but within background levels (the background comparison was conducted only for inorganic chemicals), and evaluated separately from site-related chemicals.

* = Selected as a COPC.

TABLE 3-3
SUMMARY OF CHEMICALS DETECTED IN OU3 SURFACE WATER
PCBs & PESTICIDES AREAS
(Concentrations in µg/L)

Chemical	Frequency of Detection (a)	Arithmetic Mean (b)	Range of Detection Limits	Range of Detected Concentrations	Tap Water RBC (c)	Maximum Detect > RBC?	Range of Background Concentrations (d)	Site > Background? (e)
PCBs Area								
Inorganics:								
* Aluminum	5 / 5	12,400	NU	10,500 - 13,200	3,700	**Yes**	1,230 - 1,930	**Yes**
Barium	5 / 5	66.2	NU	58.2 - 70.0	260	No	37.7 - 41.8	---
Cadmium	4 / 5	0.130	0.100	0.100 - 0.300	1.8	No	ND	---
Calcium	5 / 5	5,920	NU	4,970 - 6,580	400,000	No	18,800 - 22,200	---
Chromium	3 / 5	9.62	10.0	11.1 - 14.8	18	No	10.8	---
Copper	5 / 5	6.74	NU	5.10 - 7.60	150	No	ND	---
* Iron	5 / 5	9,900	NU	7,900 - 10,800	1,100	**Yes**	1,905 - 2,510	**Yes**
Lead	5 / 5	7.22	NU	4.80 - 8.0	15	No	1.30 - 1.90	---
Magnesium	5 / 5	2,520	NU	2,460 - 2,570	80,500	No	5,970 - 7,500	---
b Manganese	5 / 5	238	NU	171 - 318	88	**Yes**	176 - 303	No
Potassium	5 / 5	3,660	NU	3,530 - 3,990	100,000	No	2,870 - 3,670	---
Sodium	5 / 5	2,230	NU	2,130 - 2,350	100,000	No	12,500 - 16,500	---
Thallium	4 / 5	0.130	0.100	0.100 - 0.200	0.29	No	ND	---
Vanadium	5 / 5	23.2	NU	17.5 - 25.3	26	No	ND	---
Zinc	5 / 5	43.9	NU	30.7 - 50.4	1,100	No	ND	---
Pesticides Area								
Organics:								
Fluoranthene	2 / 5	0.0158	0.0200	0.023 - 0.026	150	No	ND	---
Inorganics:								
* Aluminum	5 / 5	13,800	NU	11,900 - 16,100	3,700	**Yes**	1,230 - 1,930	**Yes**
Barium	5 / 5	77.5	NU	68.1 - 109	260	No	37.7 - 41.8	---
Cadmium	3 / 5	0.100	0.100	0.1 - 0.2	1.8	No	ND	---
Calcium	5 / 5	7,370	NU	4,840 - 8,600	400,000	No	18,800 - 22,200	---
Chromium	5 / 5	11.5	NU	10.3 - 12.6	18	No	10.8	---
Copper	5 / 5	7.40	NU	6.5 - 8.2	150	No	ND	---
* Iron	5 / 5	12,900	NU	11,300 - 17,300	1,100	**Yes**	1,905 - 2,510	**Yes**
Lead	4 / 5	7.82	1.0	7.6 - 13	15	No	1.30 - 1.90	---
Magnesium	5 / 5	2,790	NU	2,660 - 2,900	80,500	No	5,970 - 7,500	---
* Manganese	5 / 5	499	NU	339 - 624	88	**Yes**	176 - 303	**Yes**
Potassium	5 / 5	3,940	NU	3,520 - 4,280	100,000	No	2,870 - 3,670	---
Sodium	5 / 5	2,460	NU	2,110 - 2,650	100,000	No	12,500 - 16,500	---

TABLE 3-3
SUMMARY OF CHEMICALS DETECTED IN OU3 SURFACE WATER
PCBs & PESTICIDES AREAS
(Concentrations in µg/L)

Chemical	Frequency of Detection (a)	Arithmetic Mean (b)	Range of Detection Limits	Range of Detected Concentrations	Tap Water RBC (c)	Maximum Detect > RBC?	Range of Background Concentrations (d)	Site > Background? (e)
Thallium	4 / 5	0.150	0.100	0.1 - 0.2	0.29	No	ND	---
* Vanadium	5 / 5	27.0	NU	24.7 - 30.1	26	**Yes**	ND	**Yes**
Zinc	5 / 5	50.2	NU	41.2 - 78	1,100	No	ND	---

(a) The number of samples in which the chemical was detected divided by the total number of samples analyzed.
(b) Calculated by averaging the detected concentration(s) with one-half the detection limit of non-detected sample(s).
(c) See Table 3-1 for a list of all Tap Water RBCs. Calcium, magnesium, potassium, and sodium are essential nutrients and do not have RBCs. Maximum concentrations of these chemicals were compared to allowable daily intake (ADI) levels.
(d) Background concentrations were site-specific and are discussed in Section 2 of the FFS.
(e) Statistical comparisons to background were not performed on organics or on inorganic chemicals with a maximum concentration below respective RBCs or ADIs.
ND = Not Detected.
NU = Not used. The chemical was detected in all samples, thus detection limits were not used to calculate mean concentrations.
b = Chemical was detected at concentrations above its Tap Water RBC or ADI but within background levels and was evaluated separately from site-related chemicals.
* = Selected as a COPC.

TABLE 3-4
SUMMARY OF CHEMICALS DETECTED IN OU3 FISH-FILLET TISSUE
DITCH AREA
(Concentrations in ug/kg-wet organics and ug/g-wet inorganics)

Chemical	Frequency of Detection (a)	Arithmetic Mean (b)	Range of Detection Limits	Range of Detected Concentrations	Fish RBC (c)	Maximum Detect > RBC?
Bass						
Organics:						
* DDD	5 / 5	16.4	NU	12.2 - 24.4	1.3E+01	**Yes**
* DDE	5 / 5	13.6	NU	10.2 - 19.3	9.3E+00	**Yes**
* PCB-1260	5 / 5	103	NU	68.5 - 157	1.6E+00	**Yes**
Inorganics:						
* Mercury	5 / 5	0.101	NU	0.0970 - 0.107	1.4E-02	**Yes**
Carp						
Organics:						
alpha Chlordane	1 / 3	1.03	1.0	2.08	2.4E+00	No
* gamma Chlordane	1 / 3	1.67	1.0	4.0	2.4E+00	**Yes**
* DDD	3 / 3	33.5	NU	13.5 - 67.2	1.3E+01	**Yes**
* DDE	3 / 3	22.6	NU	14.0 - 35.3	9.3E+00	**Yes**
* PCB-1260	3 / 3	143	NU	79.2 - 224	1.6E+00	**Yes**
Crappie						
Organics:						
* DDE	5 / 5	87.4	NU	61.4 - 108	9.3E+00	**Yes**
* PCB-1260	5 / 5	736	NU	548 - 853	1.6E+00	**Yes**
Inorganics:						
* Mercury	5 / 5	0.064	NU	0.0560 - 0.0770	1.4E-02	**Yes**
Eel						
Organics:						
* delta BHC	4 / 5	6.13	1.0	2.95 - 15.2	NRA	**Yes**
* DDD	4 / 5	95.7	1.0	24.4 - 281	1.3E+01	**Yes**
* DDE	5 / 5	102	NU	40.0 - 223	9.3E+00	**Yes**
* PCB-1260	5 / 5	1,440	NU	324 - 4,380	1.6E+00	**Yes**
Inorganics:						
* Mercury	2 / 5	0.0485	0.0480 - 0.0500	0.0670 - 0.102	1.4E-02	**Yes**

TABLE 3-4
SUMMARY OF CHEMICALS DETECTED IN OU3 FISH-FILLET TISSUE
DITCH AREA
(Concentrations in ug/kg-wet organics and ug/g-wet inorganics)

Chemical	Frequency of Detection (a)	Arithmetic Mean (b)	Range of Detection Limits	Range of Detected Concentrations	Fish RBC (c)	Maximum Detect > RBC?
Sunfish						
Organics:						
* DDE	2 / 4	3.68	1.0	3.11 - 10.6	9.3E+00	**Yes**
* PCB-1260	3 / 4	37.5	20.0	33.7 - 53.7	1.6E+00	**Yes**
White Perch						
Organics:						
DDE	3 / 5	2.57	1.0	2.78 - 5.90	9.3E+00	No
Methoxychlor	1 / 5	20	1.0	98.0	6.8E+02	No
* PCB-1260	1 / 5	12.4	20.0	22.1	1.6E+00	**Yes**
Inorganics:						
* Mercury	5 / 5	0.0940	NU	0.0850 - 0.107	1.4E-02	**Yes**

(a) The number of samples in which the chemical was detected divided by the total number of samples analyzed.
(b) Calculated by averaging the detected concentration(s) with one-half the detection limit of non-detected sample(s).
(c) See Table 3-1 for a list of all fish RBCs. Fish RBCs for organics are in ug/kg, while fish RBCs for inorganics are in ug/g.
NU = Not used. The chemical was detected in all samples, thus detection limits were not used to calculate mean concentrations.
NRA = No RBC Available.
* = Selected as a COPC.

TABLE 3-5
COMPARISON OF MAXIMUM DETECTED CONCENTRATIONS
IN OU3 SURFACE WATER TO HUMAN HEALTH AWQCs
PCBs & PESTICIDES AREAS
(Concentrations in ug/L)

Chemical	Maximum Detected Concentration	Quality Criteria for Water & Organism Human Health $1X10^{-6}$ Risk Level for Carcinogens	Maximum Detect > Criterion?
PCBs Area			
Inorganics:			
Aluminum	13,200	No value given	(a)
Barium	70.0	1,000 (b)	No
Cadmium	0.300	10 (b)	No
Calcium	6,580	No value given	(a)
Chromium (VI)	14.8	50 (b)	No
Copper	7.60	1,300	No
Iron	10,800	300 (b)	**Yes**
Lead	8.0	50 (b)	No
Magnesium	2,570	No value given	(a)
Manganese	318	50 (b)	**Yes**
Potassium	3,990	No value given	(a)
Sodium	2,350	No value given	(a)
Thallium	0.200	1.7	No
Vanadium	25.3	No value given	(a)
Zinc	50.4	No value given	(a)
Pesticides Area			
Organics:			
Fluoranthene	0.026	300	No
Inorganics:			
Aluminum	16,100	No value given	(a)
Barium	109	1,000 (b)	No
Cadmium	0.2	10 (b)	No
Calcium	8,600	No value given	(a)
Chromium (VI)	12.6	50 (b)	No
Copper	8.2	1,300	No
Iron	17,300	300 (b)	**Yes**
Lead	13	50 (b)	No
Magnesium	2,900	No value given	(a)
Manganese	624	50 (b)	**Yes**
Potassium	4,280	No value given	(a)
Sodium	2,650	No value given	(a)
Thallium	0.2	1.7	No
Vanadium	30.1	No value given	(a)
Zinc	78	No value given	(a)

(a) No value given in the 1995 Draft Quality Criteria for water.
(b) Because the "Water and Organisms" value based on IRIS toxicity criterion was not available, the value shown is the published criterion.

TABLE 3-6
SUMMARY OF CHEMICALS DETECTED IN OU3 GROUNDWATER
PCBs AREA
(Concentrations in µg/L)

Chemical	Frequency of Detection (a)	Arithmetic Mean (b)	Range of Detection Limits	Range of Detected Concentrations	Tap Water RBC (c)	Maximum Detected > RBC?	Range of Background Concentrations (d)	Site > Background? (e)
PCBs Area								
Organics:								
Acenaphthylene	1 / 15	1.08	2.0	2.19	110	No	2.01 - 6.34	---
Acetone	1 / 13	6.62	10.0	26.0	370	No	ND	---
Anthracene	2 / 15	0.144	0.100	0.305 - 1.20	1,100	No	0.113 - 2.38	---
* Dieldrin	1 / 15	0.0029	0.0050	0.0090	0.0042	**Yes**	0.0220	---
Endosulfan sulfate	1 / 15	0.0033	0.0050	0.0150	22	No	0.0108 - 0.146	---
Phenanthrene	2 / 15	0.460	0.500	0.715 - 2.93	110	No	6.39 - 8.69	---
Pyrene	1 / 15	0.0593	0.100	0.190	110	No	0.150 - 0.158	---
Inorganics:								
Aluminum	12 / 12	475	NU	96.1 - 1,450	3,700	No	94.8 - 12,500	---
b Arsenic	7 / 15	1.67	1.0	1.10 - 5.0	0.045	**Yes**	1.10 - 6.70	No
Barium	14 / 15	47.8	25.0	28.4 - 81.8	260	No	28.8 - 107	---
Cadmium	3 / 15	0.0850	0.100	0.0750 - 0.300	1.8	No	0.100 - 0.800	---
Calcium	15 / 15	6,270	NU	1,940 - 29,000	400,000	No	2,250 - 42,200	---
* Iron	15 / 15	8,750	NU	77.2 - 18,000	1,100	**Yes**	159 - 9,620	**Yes**
Lead	1 / 15	0.653	1.0	2.80	15	No	0.850 - 6.30	---
Magnesium	15 / 15	2,390	NU	1,355 - 4,040	80,500	No	191 - 7,720	---
* Manganese	15 / 15	306	NU	42.2 - 562	84	**Yes**	6.65 - 354	**Yes**
Potassium	15 / 15	973	NU	592 - 1,710	100,000	No	744 - 20,600	---
Selenium	1 / 15	1.05	2.0	1.70	18	No	2.10 - 4.20	---
Silver	1 / 15	3.05	5.0	10.7	18	No	ND	---
Sodium	11 / 11	7,310	NU	5,180 - 10,055	100,000	No	5,110 - 43,500	---
Zinc	6 / 15	48.1	20.0	20.4 - 216	1,100	No	20.3 - 46.0	---

(a) The number of samples in which the chemical was detected divided by the total number of samples analyzed, excluding samples rejected as a result of data validation.

(b) Calculated by averaging the detected concentration(s) with one-half the detection limit of non-detected sample(s).

(c) See Table 3-1 for a list of all Tap Water RBCs. Calcium, magnesium, potassium, and sodium are essential nutrients and do not have RBCs. Maximum concentrations of these chemicals were compared to allowable daily intake (ADI) levels.

(d) Background concentrations are from samples MW-52 through MW-54, and MW-63. MW-52 through MW-54 were sampled in two rounds and MW-63 was sampled in three rounds.

(e) Statistical comparisons to background data were performed only for inorganics that exceed respective RBCs or ADIs.

b = Chemical was detected at concentrations above its tap water RBC or ADI but within background levels and was evaluated separately from site-related chemicals.

ND = Not detected.

NU = Not used. The chemical was detected in all samples, thus detection limits were not used to calculate mean concentrations.

* = Selected as a COPC.

TABLE 3-7
SUMMARY OF CHEMICALS DETECTED IN OU3 SURFACE SOIL
PCBs AREA
(Concentrations in mg/kg)

Chemical	Frequency of Detection (a)	Arithmetic Mean (b)	Range of Detection Limits	Range of Detected Concentrations	Residential Soil RBC (c)	Maximum Detected > RBC?	Range of Background Concentrations (d)	Site > Background? (e)
PCBs Area								
Organics:								
Acenaphthene	1 / 11	0.893	0.133 - 0.270	9.0	470	No	ND	---
Anthracene	3 / 11	0.510	0.0070 - 0.170	0.0140 - 5.0	2,300	No	0.0150 - 0.0280	---
* Benzo(a)anthracene	4 / 11	0.958	0.140 - 0.170	0.0020 - 10.0	0.88	**Yes**	0.0030 - 0.0050	---
* Benzo(a)pyrene	4 / 11	0.783	0.140 - 0.240	0.0060 - 8.0	0.088	**Yes**	0.0020 - 0.0080	---
* Benzo(b)fluoranthene	4 / 11	1.01	0.140 - 0.730	0.0140 - 10.0	0.88	**Yes**	0.0013 - 0.0100	---
Benzo(g,h,i)perylene	4 / 11	0.300	0.160 - 0.250	0.0140 - 2.60	230	No	0.0110	---
Benzo(k)fluoranthene	4 / 11	0.617	0.140 - 0.400	0.0060 - 6.0	8.8	No	0.001 - 0.0050	---
Chrysene	3 / 11	0.972	0.0070 - 0.270	0.0140 - 10.0	88	No	ND	---
DDE	3 / 11	0.0336	0.0030 - 0.0142	0.0070 - 0.320	1.9	No	ND	---
DDT	3 / 11	0.0565	0.0030 - 0.0096	0.0270 - 0.540	1.9	No	ND	---
* Dibenzo(a,h)anthracene	1 / 11	0.129	0.0030 - 0.270	0.740	0.088	**Yes**	ND	---
Dibenzofuran	1 / 11	0.303	0.140 - 0.170	2.60	31	No	ND	---
bis(2-Ethylhexyl)phthalate	1 / 8	0.0931	0.140 - 0.190	0.180	46	No	0.180 - 0.500	---
Fluoranthene	4 / 11	2.78	0.140 - 0.170	0.0130 - 30.0	310	No	0.0055 - 0.0180	---
Fluorene	1 / 11	0.415	0.0330 - 0.170	4.0	310	No	ND	---
* Indeno(1,2,3-c,d)pyrene	4 / 11	0.290	0.140 - 0.170	0.0220 - 2.60	0.88	**Yes**	0.0080 - 0.0100	---
1-Methylnaphthalene	1 / 3	3.78	0.133	11.2	230	No	ND	---
2-Methylnaphthalene	1 / 11	0.184	0.133 - 0.170	1.30	230	No	ND	---
Naphthalene	1 / 11	0.429	0.133 - 0.170	4.0	310	No	ND	---
* PCB-1260	7 / 11	0.178	0.0130 - 0.400	0.0210 - 0.702	0.083	**Yes**	ND	---
Phenanthrene	1 / 11	2.78	0.0330 - 0.170	30.0	230	No	0.0420 - 0.354	---
Pyrene	4 / 11	1.95	0.140 - 0.970	0.0200 - 20.0	230	No	0.0090 - 0.0230	---
Inorganics:								
b Aluminum	10 / 10	6,160	NU	596 - 10,900	7,800	**Yes**	4,740 - 14,350	No
b Arsenic	5 / 11	3.26	7.50	1.55 - 4.30	0.43	**Yes**	3.24 - 3.80	No
Barium	10 / 11	55.6	4.87	6.64 - 98.0	550	No	67.0 - 92.4	---
b Beryllium	8 / 11	0.505	0.250	0.387 - 0.976	0.15	**Yes**	0.300 - 0.814	No
Calcium	3 / 6	329	109	339 - 777	4,000,000	No	486 - 1,150	---
Chromium	10 / 11	9.91	0.974	1.74 - 20.2	39	No	9.42 - 31.3	---
Cobalt	8 / 11	6.28	2.50	4.94 - 10.9	470	No	2.47 - 16.6	---
Copper	9 / 11	9.45	3.38	6.14 - 31.5	310	No	4.83 - 12.6	---
b Iron	11 / 11	9,430	NU	1,120 - 16,500	2,300	**Yes**	7,630 - 28,100	No
Lead	10 / 11	30.9	7.50	11.3 - 166	400	No	15.5 - 22.4	---
Magnesium	8 / 11	752	138	591 - 1,460	800,000	No	881 - 2,610	---

TABLE 3-7
SUMMARY OF CHEMICALS DETECTED IN OU3 SURFACE SOIL
PCBs AREA
(Concentrations in mg/kg)

Chemical	Frequency of Detection (a)	Arithmetic Mean (b)	Range of Detection Limits	Range of Detected Concentrations	Residential Soil RBC (c)	Maximum Detected > RBC?	Range of Background Concentrations (d)	Site > Background? (e)
b Manganese	11 / 11	387	NU	46.4 - 788	180	**Yes**	112 - 875	No
Nickel	8 / 11	5.44	7.50	3.83 - 8.04	160	No	2.83 - 11.9	---
Potassium	4 / 7	293	142	257 - 911	1,000,000	No	358 - 936	---
Selenium	1 / 11	6.26	10.0 - 12.4	15.3	39	No	14.2	---
Sodium	3 / 6	224	50.0	394 - 450	1,000,000	No	380 - 487	---
Vanadium	11 / 11	21.6	NU	2.69 - 37.6	55	No	19.9 - 58.9	---
Zinc	11 / 11	49.6	NU	11.1 - 212	2,300	No	14.8 - 43.9	---

(a) The number of samples in which the chemical was detected divided by the total number of samples analyzed, excluding samples rejected as a result of data validation.
(b) Calculated by averaging the detected concentration(s) with one-half the detection limit of non-detected sample(s).
(c) See Table 3-1 for a list of all residential soil RBCs. Calcium, magnesium, potassium, and sodium are essential nutrients and do not have RBCs. Maximum concentrations of these chemicals were compared to allowable daily intake (ADI) levels.
(d) Background concentrations are from samples MW-52 through MW-54 and RIBKSS-1 through 5.
(e) Statistical comparisons to background were performed only for inorganics that exceed respective RBCs or ADIs, and that had at least five site and five background samples.
b = Chemical was detected at concentrations above its residential soil RBC or ADI, but within background levels and was evaluated separately from site related chemicals.
ND = Not detected.
NU = Not used. The chemical was detected in all samples, thus detection limits were not used to calculate mean concentrations.
* = Selected as a COPC.

TABLE 3-8
SUMMARY OF CHEMICALS DETECTED IN OU3 SUBSURFACE SOIL
PCBs AREA
(Concentrations in mg/kg)

Chemical	Frequency of Detection (a)	Arithmetic Mean (b)	Range of Detection Limits	Range of Detected Concentrations	Industrial Soil RBC (c)	Maximum Detected > RBC?	Range of Background Concentrations (d)	Site > Background? (e)
PCBs Area								
Organics:								
PCB-1260	1 / 10	0.0239	0.0130	0.181	0.74	No	ND	---
Inorganics:								
Aluminum	9 / 9	8,360	NU	3,740 - 14,300	100,000	No	5,945 - 18,200	---
Barium	5 / 10	51.0	40.0	52.7 - 112	14,000	No	67.4 - 73.8	---
Beryllium	8 / 10	0.569	0.200	0.180 - 1.29	1.3	No	0.346 - 1.02	---
Calcium	2 / 3	817	100	1,030 - 1,370	4,000,000	No	113 - 454	---
Chromium	10 / 10	16.2	NU	5.63 - 30.3	1,000	No	3.66 - 25.0	---
Cobalt	8 / 10	7.62	2.0	3.22 - 27.8	12,000	No	4.56 - 13.9	---
Copper	8 / 8	12.7	NU	4.43 - 32.1	8,200	No	1.52 - 16.9	---
Iron	7 / 7	12,200	NU	5,830 - 19,600	61,000	No	2,490 - 27,800	---
Lead	4 / 10	6.91	7.50	10.1 - 13.6	400	No	7.38 - 11.8	---
Magnesium	8 / 8	1,780	NU	749 - 3,950	800,000	No	366 - 3,700	---
Manganese	3 / 3	234	NU	151 - 363	4,700	No	32.8 - 617	---
Nickel	9 / 10	9.78	2.0	2.52 - 36.0	4,100	No	4.40 - 17.9	---
Potassium	1 / 1	NC	NU	844	1,000,000	No	148 - 624	---
Selenium	1 / 10	6.13	10.0	16.3	1,000	No	16.1	---
Sodium	2 / 2	570	NU	439 - 701	1,000,000	No	320 - 933	---
Vanadium	7 / 7	39.6	NU	16.6 - 63.4	1,400	No	6.90 - 25.8	---
Zinc	6 / 6	40.1	NU	24.8 - 103	61,000	No	5.45 - 46.3	---

(a) The number of samples in which the chemical was detected divided by the total number of samples analyzed, excluding samples rejected as a result of data validation.

(b) Calculated by averaging the detected concentration(s) with one-half the detection limit of non-detected sample(s).

(c) See Table 3-1 for a list of all industrial soil RBCs. Calcium, magnesium, potassium, and sodium are essential nutrients and do not have RBCs. Maximum concentrations of these chemicals were compared to allowable daily intake (ADI) levels.

(d) Background concentrations are from samples MW-52 through MW-54, each at two depths.

(e) Statistical comparisons to background were performed only for inorganics that exceed respective RBCs or ADIs.

ND = Not detected.

NU = Not used. The chemical was detected in all samples, thus detection limits were not used to calculate mean concentrations.

TABLE 3-9

SUMMARY OF CHEMICALS OF POTENTIAL CONCERN AT OU3

CHEMICAL	SEDIMENT PCBs Area	SEDIMENT Pesticides Area	SURFACE WATER PCBs Area	SURFACE WATER Pesticides Area	FISH	GROUNDWATER	SURFACE SOIL	SUBSURFACE SOIL
Organic Chemicals								
Benzo(a)anthracene							X	
Benzo(a)pyrene	X	X					X	
Benzo(b)fluoranthene							X	
delta-BHC					X			
gamma-Chlordane					X			
DDD					X			
DDE					X			
Dibenz(a,h)anthracene							X	
Dieldrin						X		
Indeno(1,2,3-c,d)pyrene							X	
PCB-1260	X				X		X	
Inorganic Chemicals								
Aluminum	b	b	X	X			b	
Arsenic						b	b	
Beryllium	b	b					b	
Iron	b	b	X	X		X	b	
Manganese	b	b	b	X		X	b	
Mercury					X			
Vanadium	b	b		X				

X = Selected as a COPC.

b = Inorganic chemical within background levels, but above residential soil RBCs (for surface soil and sediment), industrial soil RBCs (for subsurface soil), or tap water RBCs (for groundwater and surface water).

TABLE 3-10

POTENTIAL HUMAN EXPOSURE PATHWAYS UNDER CURRENT LAND-USE CONDITIONS AT OU3

Exposure Medium	Potential Receptor	Exposure Route	Pathway Potentially Complete? Basis.	Method of Evaluation
Sediment	Security guards, on-site workers	• Incidental ingestion • Dermal contact	No. These receptors would not be likely to contact sediment from the PCBs and Pesticides Areas under current land-use conditions, thus exposures to COPCs in sediment would not be likely to occur.	None.
	Trespassers/ recreational users, environmental educators	• Incidental ingestion • Dermal contact	Yes. Because these areas are not restricted, trespassers, recreational users, and environmental educators could come into contact with COPCs in sediment from the PCBs and Pesticides Areas. However, exposures to environmental educators are limited under current land-use conditions.	Quantitative for incidental ingestion and dermal absorption for trespassers/recreational users.
Surface water	Security guards, on-site workers	• Incidental ingestion • Dermal contact	No. These receptors would not be likely to contact surface water from the PCBs and Pesticides Areas, thus exposures to COPCs in surface water would not be likely to occur.	None.
	Trespassers/ recreational users, environmental educators	• Incidental ingestion • Dermal contact	Yes. Trespassers, recreational users, and environmental educators could come into contact with COPCs in surface water from the PCBs and Pesticides Areas while wading or playing. However, exposures to environmental educators are limited under current land-use conditions.	Quantitative for dermal absorption for trespassers/ recreational users.
Fish	Workers, trespassers/ recreational users	• Ingestion	No. Fishing does not occur in the OU3 ditches; individuals fishing would more likely fish in better areas, such as along Marumsco Creek or Occoquan Bay.	None.
Groundwater	Workers, trespassers/ recreational users	• Ingestion	No. Groundwater is not used for any purpose at WRF, thus exposures to groundwater do not occur.	None.
Surface soil	On-site workers, environmental educators	• Incidental ingestion • Dermal contact	Yes. Although workers could contact surface soil, their exposures would be limited under current land-use conditions, since they are not outdoors on a frequent basis. Exposures to environmental educators could occur, but are limited under current land-use conditions.	None.

TABLE 3-10

POTENTIAL HUMAN EXPOSURE PATHWAYS UNDER CURRENT LAND-USE CONDITIONS AT OU3 (continued)

Exposure Medium	Potential Receptor	Exposure Route	Pathway Potentially Complete? Basis.	Method of Evaluation
Surface soil (cont.)	Trespassers/ recreational users	• Incidental ingestion • Dermal contact	Yes. Trespassers and recreational users could come into contact with COPCs in surface soil at OU3.	Quantitative for incidental ingestion and dermal absorption for trespassers/recreational users.

TABLE 3-11

POTENTIAL HUMAN EXPOSURE PATHWAYS UNDER HYPOTHETICAL FUTURE LAND-USE CONDITIONS AT OU3

Exposure Medium	Potential Receptor	Exposure Route	Pathway Potentially Complete? Basis.	Method of Evaluation
Sediment	Workers	• Incidental ingestion • Dermal contact	Yes. COPCs are present in sediment from both the PCBs and Pesticides Areas, and future maintenance or construction workers could contact sediment and be exposed to COPCs via incidental ingestion and dermal absorption.	Quantitative for incidental ingestion and dermal absorption.
	Residents	• Incidental ingestion • Dermal contact	Yes. COPCs are present in sediment from the PCBs and Pesticides Areas, and hypothetical future child residents could contact sediment and be exposed to COPCs via incidental ingestion and dermal absorption.	Quantitative for incidental ingestion and dermal absorption.
	Environmental educators	• Incidental ingestion • Dermal contact	Yes. COPCs are present in sediment from the PCBs and Pesticides Areas, and environmental educators could contact sediment and be exposed to COPCs via incidental ingestion and dermal absorption while conducting environmental programs.	Quantitative for incidental ingestion and dermal absorption.
Surface water	Workers	• Dermal contact	No. Workers would not be likely to contact surface water from the PCBs and Pesticides Areas, and any exposures that they may have would be of short duration and likely over a small body surface area.	None.
	Residents	• Dermal contact	Yes. COPCs are present in surface water, and hypothetical future child residents could contact surface water from the PCBs and Pesticides Areas and be exposed to COPCs via dermal absorption while wading or playing.	Quantitative for dermal absorption.
	Environmental educators	• Dermal contact	Yes. COPCs are present in surface water, and environmental educators could contact surface water from the PCBs and Pesticides Areas and be exposed to COPCs via dermal absorption while conducting educational programs.	Quantitative for dermal absorption.
Fish	Workers	• Ingestion	Yes. Although workers could feasibly fish in the OU3 ditches, it is quite unlikely that this would occur, since they would more likely fish in better areas, such as Marumsco Creek and Occoquan Bay.	None.
	Residents	• Ingestion	Yes. COPCs were detected in fish caught from OU3, and although very unlikely, it is possible that future adult residents at OU3 could consume the fish they catch from the PCBs Area ditches.	Quantitative for ingestion.

TABLE 3-11

POTENTIAL HUMAN EXPOSURE PATHWAYS UNDER HYPOTHETICAL FUTURE LAND-USE CONDITIONS AT OU3 (continued)

Exposure Medium	Potential Receptor	Exposure Route	Pathway Potentially Complete? Basis.	Method of Evaluation
Groundwater	Residents	• Ingestion • Dermal contact • Inhalation	Yes. Child and adult residents could be exposed to COPCs in groundwater used for drinking water or for bathing. VOCs were not selected as COPCs in groundwater, thus inhalation exposures while showering were not evaluated.	Quantitative for ingestion and dermal contact.
	Workers	• Ingestion • Dermal contact	Yes. Workers could be exposed to COPCs in groundwater that is used for drinking water. Due to the low exposure frequency and small surface area, dermal exposures to workers would be limited.	Quantitative for ingestion.
Soil	Residents	• Ingestion • Dermal contact	Yes. Child and adult residents could be exposed to COPCs in surface soil via incidental ingestion and dermal absorption while out in their yards.	Quantitative for ingestion and dermal contact.
	Workers	• Ingestion • Dermal contact	Yes. Workers could be exposed to COPCs in surface soil via incidental ingestion and dermal absorption while performing maintenance activities at OU3.	Quantitative for ingestion and dermal contact.
	Environmental Educators	• Ingestion • Dermal contact	Yes. Environmental educators could be exposed to COPCs in surface soil via incidental ingestion and dermal absorption while performing educational programs at OU3.	Quantitative for ingestion and dermal contact.

TABLE 3-12
EXPOSURE POINT CONCENTRATIONS FOR CHEMICALS OF POTENTIAL CONCERN
AT WOODBRIDGE RESEARCH FACILITY - OU3

Chemical	Arithmetic Mean	Maximum Detected Concentration	95% UCL	Exposure Point Concentration
SEDIMENT (mg/kg)				
PCBs Area				
Organics:				
Benzo(a)pyrene	0.235	0.596	14.1	0.596 *
PCB-1260	2.26	6.04	34,500	6.04 *
Inorganics:				
b Aluminum	12,300	15,900	16,300	15,900 *
b Beryllium	1.44	2.44	2.19	2.19
b Iron	16,500	19,400	22,700	19,400 *
b Manganese	396	564	650	564 *
b Vanadium	42.6	57.9	56.2	56.2
Pesticides Area				
Organics:				
Benzo(a)pyrene	0.0494	0.109	0.29	0.109 *
Inorganics:				
b Aluminum	13,900	15,600	16,800	15,600 *
b Beryllium	1.22	1.93	2.01	1.93 *
b Iron	22,200	34,600	31,500	31,500
b Manganese	356	391	441	391 *
b Vanadium	51.9	68.8	63	63
SURFACE WATER (µg/L)				
PCBs Area				
Inorganics:				
Aluminum	12,400	13,200	13,600	13,200 *
Iron	9,900	10,800	11,300	10,800 *
b Manganese	238	318	324	318 *
Pesticides Area				
Inorganics:				
Aluminum	13,800	16,100	15,400	15,400
Iron	12,900	17,300	15,600	15,600
Manganese	499	624	689	624 *
Vanadium	27.0	30.1	29.3	29.3
FISH FILLET TISSUE (µg/kg - wet organics; mg/kg - wet inorganics)				
Bass				
Organics:				
DDD	16.4	24.4	22.7	22.7
DDE	13.6	19.3	17.7	17.7
PCB-1260	103	157	149	149
Inorganics:				
Mercury	0.101	0.107	0.106	0.106
Carp				
Organics:				
gamma Chlordane	1.67	4.0	1,230,000	4.0 *
DDD	33.5	67.2	18,000	67.2 *

TABLE 3-12
EXPOSURE POINT CONCENTRATIONS FOR CHEMICALS OF POTENTIAL CONCERN
AT WOODBRIDGE RESEARCH FACILITY - OU3

Chemical	Arithmetic Mean	Maximum Detected Concentration	95% UCL	Exposure Point Concentration
DDE	22.6	35.3	207	35.3 *
PCB-1260	143	224	1,640	224 *
Crappie				
Organics:				
DDE	87.4	108	114	108 *
PCB-1260	736	853	892	853 *
Inorganics:				
Mercury	0.064	0.077	0.0725	0.0725
Eel				
Organics:				
delta BHC	6.13	15.2	502	15.2 *
DDD	95.7	281	1,010,000,000	281 *
DDE	102	223	293	223 *
PCB-1260	1,440	4,380	17,000	4,380 *
Inorganics:				
Mercury	0.0485	0.102	0.176	0.102 *
Sunfish				
Organics:				
DDE	3.68	10.6	26,500	10.6 *
PCB-1260	37.5	53.7	500	53.7 *
White Perch				
Organics:				
PCB-1260	12.4	22.1	20	20
Inorganics:				
Mercury	0.0940	0.107	0.105	0.105
GROUNDWATER (µg/L)				
PCBs Area				
Organics:				
Dieldrin	0.00293	0.0090	0.0034	0.0034
Inorganics:				
b Arsenic	1.67	5.0	3.25	3.25
Iron	8,750	18,000	588,000	18,000 *
Manganese	306	562	584	562 *
SURFACE SOIL (mg/kg)				
PCBs Area				
Organics:				
Benzo(a)anthracene	0.958	10.0	31.7	10.0 *
Benzo(a)pyrene	0.783	8.0	8.76	8.0 *
Benzo(b)fluoranthene	1.01	10.0	8.40	8.40
Dibenz(a,h)anthracene	0.129	0.740	14.2	0.740 *
Indeno(1,2,3-c,d)pyrene	0.290	2.60	0.769	0.769
PCB-1260	0.178	0.702	1.69	0.702 *

TABLE 3-12
EXPOSURE POINT CONCENTRATIONS FOR CHEMICALS OF POTENTIAL CONCERN
AT WOODBRIDGE RESEARCH FACILITY - OU3

Chemical	Arithmetic Mean	Maximum Detected Concentration	95% UCL	Exposure Point Concentration
Inorganics:				
b Aluminum	6,160	10,900	35,800	10,900 *
b Arsenic	3.26	4.30	4.04	4.04
b Beryllium	0.505	0.976	1.06	0.976 *
b Iron	9,430	16,500	36,700	16,500 *
b Manganese	387	788	1,220	788 *

(a) The units for the organic compounds were converted from ug/kg to mg/kg for use in calculating potential risks.

b = Chemical was detected at concentrations above its RBC or ADI, but within background concentrations and was evaluated separately from site-related chemicals.

NC = Not calculated because of low sample size.

*** = Indicates RME concentration is the maximum detected concentration.**

TABLE 3-13

EXPOSURE PARAMETERS FOR INCIDENTAL INGESTION OF CHEMICALS IN SEDIMENT AND SURFACE SOIL
BY TRESPASSERS/RECREATIONAL USERS AT OU3
[CURRENT LAND-USE CONDITIONS]

$$(L)ADD_{pot} = \frac{C_s * IR * EF * ED * Bio * CF}{BW * AT * Days}$$

Parameter	Parameter Abbreviation	Reasonable Maximum Exposure (RME) Case	Source
Potential (Lifetime) Average Daily Dose (mg/kg-day)	$(L)ADD_{pot}$	--	--
Chemical Concentration in Sediment or Soil (mg/kg)	C_s	See Table 3-12	--
Ingestion Rate (mg/day)	IR	100	EPA 1991a
Exposure Frequency (days/year)	EF	50	Assumed
Exposure Duration (years)	ED	10	Assumed
Bioavailability Factor (unitless)	Bio	1.0	Assumed
Conversion Factor	CF	$kg/10^6$ mg	--
Body Weight (kg)	BW	45	EPA 1985b
Averaging time (years)	AT		
Carcinogens		70	EPA 1991a
Noncarcinogens		10	EPA 1991a
Conversion Factor (days/year)	Days	365	--

TABLE 3-14

EXPOSURE PARAMETERS FOR DERMAL ABSORPTION OF CHEMICALS IN SEDIMENT OR SOIL
BY TRESPASSERS/RECREATIONAL USERS AT OU3
[CURRENT LAND-USE CONDITIONS]

$$(L)ADD_{int} = \frac{C_s * SA * AF * Ab * EF * ED * CF}{BW * AT * Days}$$

Parameter	Parameter Abbreviation	Reasonable Maximum Exposure (RME) Case	Source
Internal (Lifetime) Average Daily Dose (mg/kg-day)	$(L)ADD_{int}$	--	--
Chemical Concentration in Sediment or Soil (mg/kg)	C_s	See Table 3-12	--
Skin Surface Area Available for Contact (cm^2)	SA	4,600	EPA 1985b
Soil-to-Skin Adherence Factor (mg/cm^2-day)	AF	1.0	EPA 1992b
Dermal Absorption Factor (percent)	Ab		EPA 1995c
PAHs		10	
PCBs		6	
Inorganics		1	
Exposure Frequency (days/year)	EF	50	Assumed
Exposure Duration (years)	ED	10	Assumed
Conversion Factor	CF	$kg/10^6$ mg	--
Body Weight (kg)	BW	45	EPA 1985b
Averaging time (years)	AT		
Carcinogens		70	EPA 1991a
Noncarcinogens		10	EPA 1991a
Conversion Factor (days/year)	Days	365	--

TABLE 3-15

EXPOSURE PARAMETERS FOR DERMAL ABSORPTION OF CHEMICALS IN SURFACE WATER WHILE WADING
BY TRESPASSERS/RECREATIONAL USERS AT OU3
[CURRENT LAND-USE CONDITIONS]

$$(L)ADD_{int} = \frac{DA * SA * EV * EF * ED}{BW * AT * Days}$$

Parameter	Parameter Abbreviation	Reasonable Maximum Exposure (RME) Case	Source
Internal (Lifetime) Average Daily Dose (mg/kg-day)	$(L)ADD_{int}$	--	--
Dose Absorbed Per Unit Area Per Event (mg/cm^2-event)	DA	Calculated value	--
Skin Surface Area Available for Contact (cm^2)	SA	4,600	EPA 1985b
Event Frequency (events/day)	EV	1	Assumed
Exposure Frequency (days/year)	EF	50	Assumed
Exposure Duration (years)	ED	10	Assumed
Body Weight (kg)	BW	45	EPA 1985b
Averaging time (years)	AT		
Carcinogens		70	EPA 1991a
Noncarcinogens		10	EPA 1991a
Conversion Factor (days/year)	Days	365	--

TABLE 3-16

EXPOSURE PARAMETERS FOR INCIDENTAL INGESTION OF CHEMICALS IN SEDIMENT BY WORKERS AT OU3
[FUTURE LAND-USE CONDITIONS]

$$(L)ADD_{pot} = \frac{C_s * IR * EF * ED * Bio * CF}{BW * AT * Days}$$

Parameter	Parameter Abbreviation	Reasonable Maximum Exposure (RME) Case	Source
Potential (Lifetime) Average Daily Dose (mg/kg-day)	$(L)ADD_{pot}$	--	--
Chemical Concentration in Sediment (mg/kg)	C_s	See Table 3-12	--
Ingestion Rate (mg/day)	IR	480	EPA 1991a
Exposure Frequency (days/year)	EF	50	Assumed
Exposure Duration (years)	ED	1	Assumed
Bioavailability Factor (unitless)	Bio	1.0	Assumed
Conversion Factor	CF	$kg/10^6$ mg	--
Body Weight (kg)	BW	70	EPA 1991a
Averaging time (years)	AT		
Carcinogens		70	EPA 1991a
Noncarcinogens		1	EPA 1991a
Conversion Factor (days/year)	Days	365	--

TABLE 3-17

EXPOSURE PARAMETERS FOR DERMAL ABSORPTION OF CHEMICALS IN SEDIMENT BY WORKERS AT OU3
[FUTURE LAND-USE CONDITIONS]

$$(L)ADD_{int} = \frac{C_s * SA * AF * Ab * EF * ED * CF}{BW * AT * Days}$$

Parameter	Parameter Abbreviation	Reasonable Maximum Exposure (RME) Case	Source
Internal (Lifetime) Average Daily Dose (mg/kg-day)	$(L)ADD_{int}$	--	--
Chemical Concentration in Sediment (mg/kg)	C_s	See Table 3-12	--
Skin Surface Area Available for Contact (cm^2)	SA	3,500	EPA 1985b
Soil-to-Skin Adherence Factor (mg/cm^2-day)	AF	1.0	EPA 1992b
Dermal Absorption Factor (dimensionless)	Ab		EPA 1995c
PAHs		10	
PCBs		6	
Inorganics		1	
Exposure Frequency (days/year)	EF	50	Assumed
Exposure Duration (years)	ED	1	Assumed
Conversion Factor	CF	$kg/10^6$ mg	--
Body Weight (kg)	BW	70	EPA 1991a
Averaging time (years)	AT		
Carcinogens		70	EPA 1991a
Noncarcinogens		1	EPA 1991a
Conversion Factor (days/year)	Days	365	--

TABLE 3-18

EXPOSURE PARAMETERS FOR INCIDENTAL INGESTION OF CHEMICALS IN SEDIMENT AND SOIL BY ENVIRONMENTAL EDUCATORS AT OU3
[FUTURE LAND-USE CONDITIONS]

$$(L)ADD_{pot} = \frac{C_s * IR * EF * ED * Bio * CF}{BW * AT * Days}$$

Parameter	Parameter Abbreviation	Reasonable Maximum Exposure (RME) Case	Source
Potential (Lifetime) Average Daily Dose (mg/kg-day)	$(L)ADD_{pot}$	--	--
Chemical Concentration in Sediment or Soil (mg/kg)	C_s	See Table 3-12	--
Ingestion Rate (mg/day)	IR	100	EPA 1991a
Exposure Frequency (days/year)	EF	250	EPA 1991a
Exposure Duration (years)	ED	25	EPA 1991a
Bioavailability Factor (unitless)	Bio	1.0	Assumed
Conversion Factor	CF	$kg/10^6$ mg	--
Body Weight (kg)	BW	70	EPA 1991a
Averaging time (years)	AT		
Carcinogens		70	EPA 1991a
Noncarcinogens		25	EPA 1991a
Conversion Factor (days/year)	Days	365	--

TABLE 3-19

EXPOSURE PARAMETERS FOR DERMAL ABSORPTION OF CHEMICALS IN SEDIMENT OR SOIL BY ENVIRONMENTAL EDUCATORS AT OU3
[FUTURE LAND-USE CONDITIONS]

$$(L)ADD_{int} = \frac{C_s * SA * AF * Ab * EF * ED * CF}{BW * AT * Days}$$

Parameter	Parameter Abbreviation	Reasonable Maximum Exposure (RME) Case	Source
Internal (Lifetime) Average Daily Dose (mg/kg-day)	$(L)ADD_{int}$	--	--
Chemical Concentration in Sediment (mg/kg)	C_s	See Table 3-12	--
Skin Surface Area Available for Contact (cm^2)	SA	3,500	EPA 1985b
Soil-to-Skin Adherence Factor (mg/cm^2-day)	AF	1.0	EPA 1992b
Dermal Absorption Factor (dimensionless)	Ab		EPA 1995c
PAHs		10	
PCBs		6	
Inorganics		1	
Exposure Frequency (days/year)	EF	250	EPA 1991a
Exposure Duration (years)	ED	25	EPA 1991a
Conversion Factor	CF	$kg/10^6$ mg	--
Body Weight (kg)	BW	70	EPA 1991a
Averaging time (years)	AT		
Carcinogens		70	EPA 1991a
Noncarcinogens		25	EPA 1991a
Conversion Factor (days/year)	Days	365	--

TABLE 3-20

EXPOSURE PARAMETERS FOR INCIDENTAL INGESTION OF CHEMICALS IN SEDIMENT BY CHILD RESIDENTS AT OU3
[FUTURE LAND-USE CONDITIONS]

$$(L)ADD_{pot} = \frac{C_s * IR * EF * ED * Bio * CF}{BW * AT * Days}$$

Parameter	Parameter Abbreviation	Reasonable Maximum Exposure (RME) Case	Source
Potential (Lifetime) Average Daily Dose (mg/kg-day)	$(L)ADD_{pot}$	--	--
Chemical Concentration in Sediment (mg/kg)	C_s	See Table 3-12	--
Ingestion Rate (mg/day)	IR	200	EPA 1991a
Exposure Frequency (days/year)	EF	100	Assumed
Exposure Duration (years)	ED	6	EPA 1991a
Bioavailability Factor (unitless)	Bio	1.0	Assumed
Conversion Factor	CF	$kg/10^6$ mg	--
Body Weight (kg)	BW	15	EPA 1991a
Averaging time (years)	AT		
Carcinogens		70	EPA 1991a
Noncarcinogens		6	EPA 1991a
Conversion Factor (days/year)	Days	365	--

TABLE 3-21

EXPOSURE PARAMETERS FOR DERMAL ABSORPTION OF CHEMICALS IN SEDIMENT BY CHILD RESIDENTS AT OU3
[FUTURE LAND-USE CONDITIONS]

$$(L)ADD_{int} = \frac{C_s * SA * AF * Ab * EF * ED * CF}{BW * AT * Days}$$

Parameter	Parameter Abbreviation	Reasonable Maximum Exposure (RME) Case	Source
Internal (Lifetime) Average Daily Dose (mg/kg-day)	$(L)ADD_{int}$	--	--
Chemical Concentration in Sediment (mg/kg)	C_s	See Table 3-12	--
Skin Surface Area Available for Contact (cm^2)	SA	2,200	EPA 1985b
Soil-to-Skin Adherence Factor (mg/cm^2-day)	AF	1.0	EPA 1992b
Dermal Absorption Factor (percent)	Ab		EPA 1995c
PAHs		10	
PCBs		6	
Inorganics		1	
Exposure Frequency (days/year)	EF	100	Assumed
Exposure Duration (years)	ED	6	EPA 1991a
Conversion Factor	CF	$kg/10^6$ mg	--
Body Weight (kg)	BW	15	EPA 1991a
Averaging time (years)	AT		
Carcinogens		70	EPA 1991a
Noncarcinogens		6	EPA 1991a
Conversion Factor (days/year)	Days	365	--

TABLE 3-22

EXPOSURE PARAMETERS FOR DERMAL ABSORPTION OF CHEMICALS IN SURFACE WATER BY ENVIRONMENTAL EDUCATORS AT OU3
[FUTURE LAND-USE CONDITIONS]

$$(L)ADD_{int} = \frac{DA * SA * EV * EF * ED}{BW * AT * Days}$$

Parameter	Parameter Abbreviation	Reasonable Maximum Exposure (RME) Case	Source
Internal (Lifetime) Average Daily Dose (mg/kg-day)	$(L)ADD_{int}$	--	--
Dose Absorbed Per Unit Area Per Event (mg/cm^2-event)	DA	Calculated value	--
Skin Surface Area Available for Contact (cm^2)	SA	3,500	EPA 1985b
Event Frequency (events/day)	EV	1	Assumed
Exposure Frequency (days/year)	EF	100	Assumed
Exposure Duration (years)	ED	25	EPA 1991a
Body Weight (kg)	BW	70	EPA 1991a
Averaging time (years)	AT		
Carcinogens		70	EPA 1991a
Noncarcinogens		25	EPA 1991a
Conversion Factor (days/year)	Days	365	--

TABLE 3-23

EXPOSURE PARAMETERS FOR DERMAL ABSORPTION OF CHEMICALS IN SURFACE WATER WHILE WADING BY CHILD RESIDENTS AT OU3
[FUTURE LAND-USE CONDITIONS]

$$(L)ADD_{int} = \frac{DA * SA * EV * EF * ED}{BW * AT * Days}$$

Parameter	Parameter Abbreviation	Reasonable Maximum Exposure (RME) Case	Source
Internal (Lifetime) Average Daily Dose (mg/kg-day)	$(L)ADD_{int}$	--	--
Dose Absorbed Per Unit Area Per Event (mg/cm^2-event)	DA	Calculated value	--
Skin Surface Area Available for Contact (cm^2)	SA	2,200	EPA 1985b
Event Frequency (events/day)	EV	1	Assumed
Exposure Frequency (days/year)	EF	100	Assumed
Exposure Duration (years)	ED	6	EPA 1991a
Body Weight (kg)	BW	15	EPA 1991a
Averaging time (years)	AT		
Carcinogens		70	EPA 1991a
Noncarcinogens		6	EPA 1991a
Conversion Factor (days/year)	Days	365	--

TABLE 3-24

EXPOSURE PARAMETERS FOR INGESTION OF CHEMICALS IN FISH BY ADULT RESIDENTS AT OU3
[FUTURE LAND-USE CONDITIONS]

$$(L)ADD_{pot} = \frac{C_{fish} * IR * EF * ED * CF}{BW * AT * Days}$$

Parameter	Parameter Abbreviation	Reasonable Maximum Exposure (RME) Case	Source
Potential (Lifetime) Average Daily Dose (mg/kg-day)	$(L)ADD_{pot}$	--	--
Chemical Concentration in Fish (mg/kg)	C_{fish}	See Table 3-12	--
Ingestion Rate (g/day)	IR	54	EPA 1991a
Exposure Frequency (days/year)	EF	175	EPA 1991a
Exposure Duration (years)	ED	30	EPA 1991a
Conversion Factor	CF	$mg/10^3$ μg	--
Body Weight (kg)	BW	70	EPA 1991a
Averaging time (years)	AT		
Carcinogens		70	EPA 1991a
Noncarcinogens		30	EPA 1991a
Conversion Factor (days/year)	Days	365	--

TABLE 3-25

EXPOSURE PARAMETERS FOR INCIDENTAL INGESTION OF CHEMICALS IN SOIL BY WORKERS AT OU3
[FUTURE LAND-USE CONDITIONS]

$$(L)ADD_{pot} = \frac{C_s * IR * EF * ED * Bio * CF}{BW * AT * Days}$$

Parameter	Parameter Abbreviation	Reasonable Maximum Exposure (RME) Case	Source
Potential (Lifetime) Average Daily Dose (mg/kg-day)	$(L)ADD_{pot}$	--	--
Chemical Concentration in Soil (mg/kg)	C_s	See Table 3-12	--
Ingestion Rate (mg/day)	IR	50	EPA 1991a
Exposure Frequency (days/year)	EF	250	EPA 1991a
Exposure Duration (years)	ED	25	EPA 1991a
Bioavailability Factor (unitless)	Bio	1.0	Assumed
Conversion Factor	CF	$kg/10^6$ mg	--
Body Weight (kg)	BW	70	EPA 1991a
Averaging time (years)	AT		
Carcinogens		70	EPA 1991a
Noncarcinogens		25	EPA 1991a
Conversion Factor (days/year)	Days	365	--

TABLE 3-26

EXPOSURE PARAMETERS FOR DERMAL ABSORPTION OF CHEMICALS IN SOIL BY WORKERS AT OU3
[FUTURE LAND-USE CONDITIONS]

$$(L)ADD_{int} = \frac{C_s * SA * AF * Ab * EF * ED * CF}{BW * AT * Days}$$

Parameter	Parameter Abbreviation	Reasonable Maximum Exposure (RME) Case	Source
Internal (Lifetime) Average Daily Dose (mg/kg-day)	$(L)ADD_{int}$	--	--
Chemical Concentration in Soil (mg/kg)	C_s	See Table 3-12	--
Skin Surface Area Available for Contact (cm^2)	SA	3,500	EPA 1985b
Soil-to-Skin Adherence Factor (mg/cm^2-day)	AF	1.0	EPA 1992b
Dermal Absorption Factor (dimensionless)	Ab		EPA 1995c
PAHs		10	
PCBs		6	
Exposure Frequency (days/year)	EF	250	Assumed
Exposure Duration (years)	ED	25	Assumed
Conversion Factor	CF	$kg/10^6$ mg	--
Body Weight (kg)	BW	70	EPA 1991a
Averaging time (years)	AT		
Carcinogens		70	EPA 1991a
Noncarcinogens		25	EPA 1991a
Conversion Factor (days/year)	Days	365	--

TABLE 3-27

EXPOSURE PARAMETERS FOR INCIDENTAL INGESTION OF CHEMICALS IN SURFACE SOIL BY RESIDENTS AT OU3
[FUTURE LAND-USE CONDITIONS]

$$(L)ADD_{pot} = \frac{C_s * IR * EF * ED * Bio * CF}{BW * AT * Days}$$

Parameter	Parameter Abbreviation	Reasonable Maximum Exposure (RME) Case		Source
		Child	Adult	
Potential (Lifetime) Average Daily Dose (mg/kg-day)	$(L)ADD_{pot}$	--	--	--
Chemical Concentration in Surface Soil (mg/kg)	C_s	--	--	--
Ingestion Rate (mg/day)	IR	200	100	EPA 1991a
Exposure Frequency (days/year)	EF	350	350	EPA 1991a
Exposure Duration (years)	ED	6	30	EPA 1991a
Bioavailability Factor (unitless)	Bio	1.0	1.0	Assumed
Conversion Factor	CF	$kg/10^6$ mg	$kg/10^6$ mg	--
Body Weight (kg)	BW	15	70	EPA 1991a
Averaging time (years)	AT			
Carcinogens		70	70	EPA 1991a
Noncarcinogens		6	30	EPA 1991a
Conversion Factor (days/year)	Days	365	365	--

TABLE 3-28

EXPOSURE PARAMETERS FOR DERMAL ABSORPTION OF CHEMICALS IN SURFACE SOIL BY RESIDENTS AT OU3
[FUTURE LAND-USE CONDITIONS]

$$(L)ADD_{int} = \frac{C_s * SA * AF * Ab * EF * ED * CF}{BW * AT * Days}$$

Parameter	Parameter Abbreviation	Reasonable Maximum Exposure (RME) Case		Source
		Child	Adult	
Internal (Lifetime) Average Daily Dose (mg/kg-day)	$(L)ADD_{int}$	--	--	--
Chemical Concentration in Surface Soil (mg/kg)	C_s	--	--	--
Skin Surface Area Available for Contact (cm^2) (a)	SA	2,200	6,400	EPA 1985
Soil-to-Skin Adherence Factor (mg/cm^2-day)	AF	1.0	1.0	EPA 1992b
Dermal Absorption Factor (percent)	Ab			
PAHs		10	10	EPA 1995c
PCBs		6	6	
Exposure Frequency (days/year)	EF	350	350	EPA 1991a
Exposure Duration (years)	ED	6	30	EPA 1991a
Conversion Factor	CF	$kg/10^6$ mg	$kg/10^6$ mg	--
Body Weight (kg)	BW	15	70	EPA 1991a
Averaging time (years)	AT			
Carcinogens		70	70	EPA 1991a
Noncarcinogens		6	30	EPA 1991a
Conversion Factor (days/year)	Days	365	365	--

(a) The values for surface area assumed that ½ arms, ½ legs, feet, and hands are available for exposures.

TABLE 3-29

EXPOSURE PARAMETERS FOR INGESTION OF CHEMICALS IN GROUNDWATER BY RESIDENTS AT OU3
[FUTURE LAND-USE CONDITIONS]

$$(L)ADD_{pot} = \frac{C_{gw} * IR * EF * ED * CF}{BW * AT * Days}$$

Parameter	Parameter Abbreviation	Reasonable Maximum Exposure (RME) Case		Source
		Child	Adult	
Potential (Lifetime) Average Daily Dose (mg/kg-day)	$(L)ADD_{pot}$	--	--	--
Chemical Concentration in Groundwater (μg/L)	C_{gw}	--	--	--
Ingestion Rate (L/day)	IR	1	2	EPA 1991a
Exposure Frequency (days/year)	EF	350	350	EPA 1991a
Exposure Duration (years)	ED	6	30	EPA 1991a
Conversion Factor	CF	$mg/10^3$ μg	$mg/10^3$ μg	--
Body Weight (kg)	BW	15	70	EPA 1991a
Averaging time (years)	AT			
Carcinogens		70	70	EPA 1991a
Noncarcinogens		6	30	EPA 1991a
Conversion Factor (days/year)	Days	365	365	--

TABLE 3-30

EXPOSURE PARAMETERS FOR DERMAL ABSORPTION OF CHEMICALS IN GROUNDWATER WHILE BATHING BY RESIDENTS AT OU2 AND OU4
[FUTURE LAND-USE CONDITIONS]

$$(L)ADD_{int} = \frac{DA * SA * EV * EF * ED}{BW * AT * Days}$$

Parameter	Parameter Abbreviation	Reasonable Maximum Exposure (RME) Case		Source
		Child	Adult	
Internal (Lifetime) Average Daily Dose (mg/kg-day)	$(L)ADD_{int}$	--	--	--
Dose Absorbed Per Unit Area Per Event (mg/cm^2-event) (a)	DA	Calculated Value	Calculated Value	--
Skin Surface Area Available for Contact (cm^2) (b)	SA	7,000	18,000	EPA 1985b
Event Frequency (events/day)	EV	1	1	Assumed
Exposure Frequency (days/year)	EF	350	350	EPA 1991a
Exposure Duration (years)	ED	6	30	EPA 1991a
Body Weight (kg)	BW	15	70	EPA 1991a
Averaging time (years)	AT			
Carcinogens		70	70	EPA 1991a
Noncarcinogens		6	30	EPA 1991a
Conversion Factor (days/year)	Days	365	365	--

(a) See text for equations on the derivation of the DA value.
(b) The values for surface area assumed that the entire body is available for exposure.

TABLE 3-31

PARAMETERS FOR EVALUATING THE DERMAL PATHWAY (a)

Chemical	Kp (b) (cm/hr)	MW (g/mol)	Log K_{ow} (---)	B (---)	Dsc (cm^2/hr)	Tau (hr)	t* Used
Organics							
Dieldrin	0.016	381	4.56	3.63	9.04E-09	18.4	93.8
Inorganics							
Aluminum	0.001	NU	NU	NU	NU	NU	NU
Iron	0.001	NU	NU	NU	NU	NU	NU
Manganese	0.001	NU	NU	NU	NU	NU	NU
Vanadium	0.001	NU	NU	NU	NU	NU	NU

(a) Only chemicals that were evaluated for the dermal pathways for surface water and groundwater are presented on this table.
(b) Kp values were estimated, using the chemical's molecular weight and log Kow (USEPA 1992b), using the chemical's molecular weight and log Kow (USEPA 1992b), except where noted.
(c) The Kp for chloroform is a measure value from USEPA (1992b).
NU = Parameter not used for this chemical.

TABLE 3-32

EXPOSURE PARAMETERS FOR INGESTION OF CHEMICALS IN GROUNDWATER BY WORKERS AT OU3
[FUTURE LAND-USE CONDITIONS]

$$(L)ADD_{pot} = \frac{C_s * IR * EF * ED * Bio * CF}{BW * AT * Days}$$

Parameter	Parameter Abbreviation	Reasonable Maximum Exposure (RME) Case	Source
Potential (Lifetime) Average Daily Dose (mg/kg-day)	$(L)ADD_{pot}$	--	--
Chemical Concentration in Groundwater (μg/L)	C_{gw}	See Table 3-12	--
Ingestion Rate (L/day)	IR	1	EPA 1991a
Exposure Frequency (days/year)	EF	250	EPA 1991a
Exposure Duration (years)	ED	25	EPA 1991a
Conversion Factor	CF	$mg/10^3$ μg	--
Body Weight (kg)	BW	70	EPA 1991a
Averaging time (years)	AT		
Carcinogens		70	EPA 1991a
Noncarcinogens		25	EPA 1991a
Conversion Factor (days/year)	Days	365	--

TABLE 3-33

CHRONIC ORAL TOXICITY CRITERIA FOR CHEMICALS OF POTENTIAL CONCERN AT OU3

	Toxicity Criteria For Carcinogenic Effects			Toxicity Criteria for Noncarcinogenic Effects			
Chemical	Oral Slope Factor $(mg/kg\text{-}day)^{-1}$	Weight-of-Evidence Classification (a)	Slope Factor Source	Chronic Oral Reference Dose (RfD) (mg/kg-day)	Uncertainty Factor (b)	Target Organ/Critical Effect (c)	RfD Source
Organics:							
Benzo(a)anthracene	7.3E-01 (d)	B2	IRIS	---	---	---	---
Benzo(a)pyrene	7.3E+00	B2	IRIS	---	---	---	---
Benzo(b)fluoranthene	7.3E-01 (d)	B2	IRIS	---	---	---	---
delta-BHC	---	D	IRIS	---	---	---	---
gamma-Chlordane (e)	1.3E+00	B2	IRIS	6E-05	1,000	Liver	IRIS
DDD	2.4E-01	B2	IRIS	---	---	---	---
DDE	3.4E-01	B2	IRIS	---	---	---	---
Dibenzo(a,h)anthracene	7.3E+00 (d)	B2	IRIS	---	---	---	---
Dieldrin	1.6E+01	B2	IRIS	5E-05	100	Liver	IRIS
Indeno(1,2,3-c,d)pyrene	7.3E-01 (d)	B2	IRIS	---	---	---	---
PCB-1260 (f)	2.0E+00	B2	IRIS	---	---	---	---
Inorganics:							
Aluminum	---	---	---	1E+00	---	---	NCEA
Beryllium	4.3E+00	B2	IRIS	5E-03	100	None observed	IRIS
Iron	---	---	---	3E-01	---	---	NCEA
Manganese	---	D	IRIS	2.4E-02	3	CNS	IRIS
Methyl mercury	---	D	IRIS	1E-04	---	CNS	IRIS
Vanadium	---	---	---	7E-03	100	None observed	HEAST

(a) USEPA weight-of-evidence classification scheme for carcinogens:
A = Human Carcinogen, sufficient evidence of carcinogenicity in humans;
B1 = Probable Human Carcinogen, limited human data are available;
B2 = Probable Human Carcinogen, sufficient evidence of carcinogenicity in animals with inadequate or lack of evidence in humans;
C = Possible Human Carcinogen, limited evidence from animal studies in the absence of human studies; and
D = Not classified as to human carcinogenicity, inadequate or no evidence.

(b) Uncertainty factors presented are the products of specific uncertainty factors and modifying factors. Uncertainty factors used to develop reference doses generally consist of multiples of 10, with each factor representing a specific area of uncertainty in the data available.
The standard uncertainty factors include:
- a 10-fold factor to account for the variation in sensitivity among the members of the human population;
- a 10-fold factor to account for the uncertainty in extrapolating animal data to the case of humans;
- a 10-fold factor to account for the uncertainty in extrapolating from less-than-chronic NOAELs to chronic NOAELs;
- a 10-fold factor to account for the uncertainty in extrapolating from LOAELs to NOAELs.

Modifying factors are applied at the discretion of the RfD reviewer to cover other uncertainties in the data and range from 1 to 10.

(c) A target organ or critical effect is the organ/effect most sensitive to the chemical exposure. RfDs are based on toxic effects in the target organ or critical effects. If an RfD is based on a study in which a target organ or critical effect was not identified, the organ/effect listed is one known to be affected by the chemical.

(d) The cancer slope factor for benzo(a)pyrene was used to evaluate carcinogenic PAHs, along with the toxic equivalency factor (TEF) approach. The TEFs used are as follows: benzo(a)anthracene, benzo(b)fluoranthene, and indeno(1,2,3-c,d)pyrene, 0.1; dibenzo(a,h)anthracene, 1.0.

(e) Toxicity criteria for chlordane was used.

(f) Because PCB-1260 is potentially carcinogenic and there is no evidence of it causing noncarcinogenic effects, only the toxicity criterion for carcinogenic effects of PCBs is presented.

--- = No information available.

CNS = Central Nervous System.

NOTE: IRIS = Integrated Risk Information System - EPA 1996.
HEAST = Health Effects Assessment Summary Tables - EPA 1995d.
NCEA = National Center for Environmental Assessment - These values were obtained from the USEPA Region III RBC table.

TABLE 3-34

ADJUSTED CHRONIC ORAL TOXICITY CRITERIA FOR CHEMICALS OF POTENTIAL CONCERN EVALUATED FOR THE DERMAL PATHWAYS

Chemical	Absolute Oral Absorption Factor	Source of Absolute Oral Absorption Factor	Slope Factor $(mg/kg\text{-}day)^{-1}$	Adjusted Slope Factor $(mg/kg\text{-}day)^{-1}$ (a)	Reference Dose (mg/kg-day)	Adjusted Reference Dose (mg/kg-day) (b)
Organics:						
Benzo(a)anthracene	1	Default value	7.3E-01	7.3E-01	---	---
Benzo(a)pyrene	1	Default value	7.3E+00	7.3E+00	---	---
Benzo(b)fluoranthene	1	Default value	7.3E-01	7.3E-01	---	---
Dibenz(a,h)anthracene	1	Default value	7.3E+00	7.3E+00	---	---
Indeno(1,2,3-c,d)pyrene	1	Default value	7.3E-01	7.3E-01	---	---
PCBs	0.93	ATSDR 1991a	2.0E+00	2.2E+00	---	---
Inorganics:						
Aluminum	1	Default value	---	---	1.0E+00	1.0E+00
Beryllium	0.005	ATSDR 1991b	4.3E+00	8.6E+02	5.0E-03	2.5E-05
Iron	1	Default value	---	---	3.0E-01	3.0E-01
Manganese	0.055	ATSDR 1990	---	---	2.4E-02	1.3E-03
Vanadium	0.03	ATSDR 1992	---	---	7.0E-03	2.1E-04

(a) Adjusted slope factors were calculated by dividing the slope factor by the absolute oral absorption factor.
(b) Adjusted reference doses were calculated by multiplying the reference dose by the absolute oral absorption factor.

TABLE 3-35
EXPOSURES AND RISKS ASSOCIATED WITH INCIDENTAL INGESTION OF SEDIMENT BY TRESPASSERS/RECREATIONAL USERS AT OU3

CURRENT LAND-USE CONDITIONS

Carcinogenic Chemical	RME Exposure Point Concentration (mg/kg)	Lifetime Average Daily Dose (mg/kg-day)	Slope Factor $(mg/kg\text{-}day)^{-1}$	Weight-of-Evidence Classification	RME Excess Lifetime Cancer Risk
PCBs Area					
Benzo(a)pyrene	0.596 *	2.59E-08	7.3E+00	B2	2E-07
PCB-1260	6.04 *	2.63E-07	2.0E+00	B2	5E-07
Total:					7E-07
Pesticides Area					
Benzo(a)pyrene	0.109 *	4.74E-09	7.3E+00	B2	3E-08
Total:					3E-08

* Denotes maximum detected concentration.

TABLE 3-36
EXPOSURES AND RISKS ASSOCIATED WITH DERMAL ABSORPTION OF CHEMICALS IN SEDIMENT BY TRESPASSERS/RECREATIONAL USERS AT OU3

CURRENT LAND-USE CONDITIONS

Carcinogenic Chemical	RME Exposure Point Concentration (mg/kg)	Lifetime Average Daily Dose (mg/kg-day)	Adjusted Slope Factor $(mg/kg\text{-}day)^{-1}$	Weight-of-Evidence Classification	RME Excess Lifetime Cancer Risk
PCBs Area					
Benzo(a)pyrene	0.596 *	1.19E-07	7.3E+00	B2	9E-07
PCB-1260	6.04 *	7.25E-07	2.2E+00	B2	2E-06
Total:					2E-06
Pesticides Area					
Benzo(a)pyrene	0.109 *	2.18E-08	7.3E+00	B2	2E-07
Total:					2E-07

* Denotes maximum detected concentration.

TABLE 3-37
EXPOSURES AND RISKS ASSOCIATED WITH DERMAL ABSORPTION OF CHEMICALS IN SURFACE WATER BY TRESPASSERS/RECREATIONAL USERS AT OU3

CURRENT LAND-USE CONDITIONS

Noncarcinogenic Chemical	RME Exposure Point Concentration (µg/L)	Average Daily Dose (mg/kg-day)	Adjusted RfD (mg/kg-day)	Target Organ/ Critical Effect	RME ADD:RfD Ratio
PCBs Area					
Inorganics					
Aluminum	13,200 *	3.70E-04	1E+00	---	4E-04
Iron	10,800 *	3.02E-04	3E-01	---	1E-03
Hazard Index:					1E-03
Pesticides Area					
Inorganics					
Aluminum	15,400	4.31E-04	1E+00	---	4E-04
Iron	15,600	4.37E-04	3E-01	---	1E-03
Manganese	624 *	1.75E-05	1E-03	CNS	1E-02
Vanadium	29.3	8.21E-07	2E-04	None observed	4E-03
Hazard Index:					2E-02

* Maximum detected concentration.
CNS = Central Nervous System

TABLE 3-38
EXPOSURES AND RISKS ASSOCIATED WITH INCIDENTAL INGESTION OF SURFACE SOIL BY TRESPASSERS/RECREATIONAL USERS AT OU3

CURRENT LAND-USE CONDITIONS

Carcinogenic Chemical	RME Exposure Point Concentration (mg/kg)	Lifetime Average Daily Dose (mg/kg-day)	Slope Factor (mg/kg-day)$^{-1}$	Weight-of-Evidence Classification	RME Excess Lifetime Cancer Risk
PCBS Area					
Organics					
Benzo(a)anthracene	10 *	4.35E-07	7.3E-01	B2	3E-07
Benzo(a)pyrene	8 *	3.48E-07	7.3E+00	B2	3E-06
Benzo(b)fluoranthene	8.4	3.65E-07	7.3E-01	B2	3E-07
Dibenz(a,h)anthracene	0.74 *	3.22E-08	7.3E+00	B2	2E-07
Indeno(1,2,3-c,d)pyrene	0.769	3.34E-08	7.3E-01	B2	2E-08
PCB-1260	0.702 *	3.05E-08	2.0E+00	B2	6E-08
Total:					3E-06

* Maximum detected concentration.

TABLE 3-39
EXPOSURES AND RISKS ASSOCIATED WITH DERMAL ABSORPTION OF CHEMICALS IN SURFACE SOIL BY TRESPASSERS/RECREATIONAL USERS AT OU3

CURRENT LAND-USE CONDITIONS

Carcinogenic Chemical	RME Exposure Point Concentration (mg/kg)	Lifetime Average Daily Dose (mg/kg-day)	Adjusted Slope Factor (mg/kg-day)$^{-1}$	Weight-of-Evidence Classification	RME Excess Lifetime Cancer Risk
PCBs Area					
Organics					
Benzo(a)anthracene	10 *	2.00E-06	7.3E-01	B2	1E-06
Benzo(a)pyrene	8 *	1.60E-06	7.3E+00	B2	1E-05
Benzo(b)fluoranthene	8.4	1.68E-06	7.3E-01	B2	1E-06
Dibenz(a,h)anthracene	0.74 *	1.48E-07	7.3E+00	B2	1E-06
Indeno(1,2,3-c,d)pyrene	0.769	1.54E-07	7.3E-01	B2	1E-07
PCB-1260	0.702 *	8.43E-08	2.2E+00	B2	2E-07
Total:					2E-05

* Maximum detected value.

TABLE 3-40
EXPOSURES AND RISKS ASSOCIATED WITH INCIDENTAL INGESTION OF SEDIMENT BY CHILD RESIDENTS AT OU3

FUTURE LAND-USE CONDITIONS

Carcinogenic Chemical	RME Exposure Point Concentration (mg/kg)	Lifetime Average Daily Dose (mg/kg-day)	Slope Factor $(mg/kg\text{-}day)^{-1}$	Weight-of-Evidence Classification	RME Lifetime Excess Cancer Risk
PCBs Area					
Benzo(a)pyrene	0.596 *	1.87E-07	7.3E+00	B2	1E-06
PCB-1260	6.04 *	1.89E-06	2.0E+00	B2	4E-06
Total:					5E-06
Pesticides Area					
Benzo(a)pyrene	0.109 *	3.41E-08	7.3E+00	B2	2E-07
Total:					2E-07

* Denotes maximum detected concentration.

TABLE 3-41
EXPOSURES AND RISKS ASSOCIATED WITH DERMAL ABSORPTION OF CHEMICALS IN SEDIMENT BY CHILD RESIDENTS AT OU3

FUTURE LAND-USE CONDITIONS

Carcinogenic Chemical	RME Exposure Point Concentration (mg/kg)	Lifetime Average Daily Dose (mg/kg-day)	Adjusted Slope Factor $(mg/kg\text{-}day)^{-1}$	Weight-of-Evidence Classification	RME Excess Lifetime Cancer Risk
PCBs Area					
Benzo(a)pyrene	0.596 *	2.05E-07	7.3E+00	B2	1E-06
PCB-1260	6.04 *	1.25E-06	2.2E+00	B2	3E-06
Total:					4E-06
Pesticides Area					
Benzo(a)pyrene	0.109 *	3.75E-08	7.3E+00	B2	3E-07
Total:					3E-07

* Denotes maximum detected concentration.

TABLE 3-42
EXPOSURES AND RISKS ASSOCIATED WITH INCIDENTAL INGESTION OF SEDIMENT BY WORKERS AT OU3

FUTURE LAND-USE CONDITIONS

Carcinogenic Chemical	RME Exposure Point Concentration (mg/kg)	Lifetime Average Daily Dose (mg/kg-day)	Slope Factor $(mg/kg\text{-}day)^{-1}$	Weight-of-Evidence Classification	RME Lifetime Excess Cancer Risk
PCBs Area					
Benzo(a)pyrene	0.596 *	8.00E-09	7.3E+00	B2	6E-08
PCB-1260	6.04 *	8.11E-08	2.0E+00	B2	2E-07
Total:					2E-07
Pesticides Area					
Benzo(a)pyrene	0.109 *	1.46E-09	7.3E+00	B2	1E-08
Total:					1E-08

* Denotes maximum detected concentration.

TABLE 3-43
EXPOSURES AND RISKS ASSOCIATED WITH DERMAL ABSORPTION OF CHEMICALS IN SEDIMENT BY WORKERS AT OU3

FUTURE LAND-USE CONDITIONS

Carcinogenic Chemical	RME Exposure Point Concentration (mg/kg)	Lifetime Average Daily Dose (mg/kg-day)	Adjusted Slope Factor $(mg/kg\text{-}day)^{-1}$	Weight-of-Evidence Classification	RME Excess Lifetime Cancer Risk
PCBs Area					
Benzo(a)pyrene	0.596 *	5.83E-09	7.3E+00	B2	4E-08
PCB-1260	6.04 *	3.55E-08	2.2E+00	B2	8E-08
Total:					1E-07
Pesticides Area					
Benzo(a)pyrene	0.109 *	1.07E-09	7.3E+00	B2	8E-09
Total:					8E-09

* Denotes maximum detected concentration.

TABLE 3-44
EXPOSURES AND RISKS ASSOCIATED WITH INCIDENTAL INGESTION OF SEDIMENT BY ENVIRONMENTAL EDUCATORS AT OU3

FUTURE LAND-USE CONDITIONS

Carcinogenic Chemical	RME Exposure Point Concentration (mg/kg)	Lifetime Average Daily Dose (mg/kg-day)	Slope Factor $(mg/kg\text{-}day)^{-1}$	Weight-of-Evidence Classification	RME Lifetime Excess Cancer Risk
PCBs Area					
Benzo(a)pyrene	0.596 *	2.08E-07	7.3E+00	B2	2E-06
PCB-1260	6.04 *	2.11E-06	2.0E+00	B2	4E-06
Total:					6E-06
Pesticides Area					
Benzo(a)pyrene	0.109 *	3.81E-08	7.3E+00	B2	3E-07
Total:					3E-07

* Denotes maximum detected concentration.

TABLE 3-45
EXPOSURES AND RISKS ASSOCIATED WITH DERMAL ABSORPTION OF CHEMICALS IN SEDIMENT BY ENVIRONMENTAL EDUCATORS AT OU3

FUTURE LAND-USE CONDITIONS

Carcinogenic Chemical	RME Exposure Point Concentration (mg/kg)	Lifetime Average Daily Dose (mg/kg-day)	Adjusted Slope Factor $(mg/kg\text{-}day)^{-1}$	Weight-of-Evidence Classification	RME Excess Lifetime Cancer Risk
PCBs Area					
Benzo(a)pyrene	0.596 *	7.29E-07	7.3E+00	B2	5E-06
PCB-1260	6.04 *	4.43E-06	2.2E+00	B2	1E-05
Total:					1E-05
Pesticides Area					
Benzo(a)pyrene	0.109 *	1.33E-07	7.3E+00	B2	1E-06
Total:					1E-06

* Denotes maximum detected concentration.

TABLE 3-46
EXPOSURES AND RISKS ASSOCIATED WITH DERMAL ABSORPTION OF CHEMICALS IN SURFACE WATER BY CHILD RESIDENTS AT OU3

FUTURE LAND-USE CONDITIONS

Noncarcinogenic Chemical	RME Exposure Point Concentration (µg/L)	Average Daily Dose (mg/kg-day)	Adjusted RfD (mg/kg-day)	Target Organ/ Critical Effect	RME ADD:RfD Ratio
PCBs Area					
Inorganics					
Aluminum	13,200 *	1.06E-03	1E+00	---	1E-03
Iron	10,800 *	8.68E-04	3E-01	---	3E-03
Hazard Index:					4E-03
Pesticides Area					
Inorganics					
Aluminum	15,400	1.24E-03	1E+00	---	1E-03
Iron	15,600	1.25E-03	3E-01	---	4E-03
Manganese	624 *	5.01E-05	1E-03	CNS	4E-02
Vanadium	29.3	2.35E-06	2E-04	None observed	1E-02
Hazard Index:					5E-02

* Maximum detected concentration.
CNS = Central Nervous System

TABLE 3-47
EXPOSURES AND RISKS ASSOCIATED WITH DERMAL ABSORPTION OF CHEMICALS IN SURFACE WATER BY ENVIRONMENTAL EDUCATORS AT OU3

FUTURE LAND-USE CONDITIONS

Noncarcinogenic Chemical	RME Exposure Point Concentration (µg/L)	Average Daily Dose (mg/kg-day)	Adjusted RfD (mg/kg-day)	Target Organ/ Critical Effect	RME ADD:RfD Ratio
PCBs Area					
Inorganics					
Aluminum	13,200 *	7.23E-04	1E+00	---	7E-04
Iron	10,800 *	5.92E-04	3E-01	---	2E-03
Hazard Index:					3E-03
Pesticides Area					
Inorganics					
Aluminum	15,400	8.44E-04	1E+00	---	8E-04
Iron	15,600	8.55E-04	3E-01	---	3E-03
Manganese	624 *	3.42E-05	1E-03	CNS	3E-02
Vanadium	29.3	1.61E-06	2E-04	None observed	8E-03
Hazard Index:					4E-02

* Maximum detected concentration.
CNS = Central Nervous System

TABLE 3-48
EXPOSURES AND RISKS ASSOCIATED WITH INGESTION OF FISH BY ADULT RESIDENTS AT OU3
FUTURE LAND-USE CONDITIONS

Carcinogenic Chemical	RME Exposure Point Concentration (mg/kg)	Lifetime Average Daily Dose (mg/kg-day)	Slope Factor $(mg/kg\text{-}day)^{-1}$	Weight-of-Evidence Classification	RME Lifetime Excess Cancer Risk
Bass					
DDD	0.023	3.60E-06	2.4E-01	B2	9E-07
DDE	0.018	2.81E-06	3.4E-01	B2	1E-06
PCB-1260	0.149	2.36E-05	7.7E+00	B2	2E-04
Total:					2E-04
Carp					
gamma-Chlordane	0.004 *	6.34E-07	1.3E+00	B2	8E-07
DDD	0.0672 *	1.07E-05	2.4E-01	B2	3E-06
DDE	0.0353 *	5.60E-06	3.4E-01	B2	2E-06
PCB-1260	0.224 *	3.55E-05	7.7E+00	B2	3E-04
Total:					3E-04
Crappie					
DDE	0.108 *	1.71E-05	3.4E-01	B2	6E-06
PCB-1260	0.853 *	1.35E-04	7.7E+00	B2	1E-03
Total:					1E-03
Eel (a)					
DDD	0.281 *	4.45E-05	2.4E-01	B2	1E-05
DDE	0.223 *	3.53E-05	3.4E-01	B2	1E-05
PCB-1260	4.38 *	6.94E-04	7.7E+00	B2	5E-03
Total:					5E-03
Sunfish					
DDE	0.0106 *	1.68E-06	3.4E-01	B2	6E-07
PCB-1260	0.0537 *	8.51E-06	7.7E+00	B2	7E-05
Total:					7E-05
White Perch					
PCB-1260	0.020	3.17E-06	7.7E+00	B2	2E-05
Total:					2E-05

Noncarcinogenic Chemical	RME Exposure Point Concentration (mg/kg)	Average Daily Dose (mg/kg-day)	RfD (mg/kg-day)	Target Organ/ Critical Effect	RME ADD:RfD Ratio
Bass					
Mercury	0.106	3.92E-05	1E-04	CNS	4E-01
Hazard Index:					4E-01
Carp					
gamma-Chlordane	0.004 *	1.48E-06	6E-05	Liver	2E-02
Hazard Index:					2E-02
Crappie					
Mercury	0.0725	2.68E-05	1E-04	CNS	3E-01
Hazard Index:					3E-01
Eel					
Mercury	0.102 *	3.77E-05	1E-04	CNS	4E-01
Hazard Index:					4E-01
White Perch					
Mercury	0.105	3.88E-05	1E-04	CNS	4E-01
Hazard Index:					4E-01

(a) delta-BHC was not evaluated due to a lack of toxicity criteria.
* Maximum detected concentration.
CNS = Central Nervous System

TABLE 3-49
EXPOSURES AND RISKS ASSOCIATED WITH INGESTION OF GROUNDWATER
BY HYPOTHETICAL FUTURE RESIDENTS AT OU3

FUTURE LAND-USE CONDITIONS

Carcinogenic Chemical	RME Exposure Point Concentration (ug/L)	Lifetime Average Daily Dose (mg/kg-day) Child	Lifetime Average Daily Dose (mg/kg-day) Adult	Slope Factor (mg/kg-day)$^{-1}$	Weight-of-Evidence Classification	RME Excess Lifetime Cancer Risk Child	RME Excess Lifetime Cancer Risk Adult
PCBs Area							
Organics							
Dieldrin	0.0034	1.9E-08	4.0E-08	1.6E+01	B2	3E-07	6E-07
Total:						3E-07	6E-07

Noncarcinogenic Chemical	RME Exposure Point Concentration (ug/L)	Average Daily Dose (mg/kg-day) Child	Average Daily Dose (mg/kg-day) Adult	RfD (mg/kg-day)	Target Organ/ Critical Effect	RME ADD:RfD Ratio Child	RME ADD:RfD Ratio Adult
PCBs Area							
Organics							
Dieldrin	0.0034	2.2E-07	9.3E-08	5E-05	Liver	4E-03	2E-03
Inorganics							
Iron	18,000 *	1.2E+00	4.9E-01	3E-01	---	4E+00	2E+00
Manganese	562 *	3.6E-02	1.5E-02	2.4E-02	CNS	1E+00	6E-01
Hazard Index:						5E+00	2E+00

CNS = Central Nervous System.
* Maximum detected concentration.

TABLE 3-50
EXPOSURES AND RISKS ASSOCIATED WITH DERMAL ABSORPTION OF CHEMICALS IN GROUNDWATER BY HYPOTHETICAL FUTURE RESIDENTS AT OU3

FUTURE LAND-USE CONDITIONS

Carcinogenic Chemical	RME Exposure Point Concentration (ug/L)	Lifetime Average Daily Dose (mg/kg-day) Child	Lifetime Average Daily Dose (mg/kg-day) Adult	Adjusted Slope Factor $(mg/kg\text{-}day)^{-1}$	Weight-of-Evidence Classification	RME Excess Lifetime Cancer Risk Child	RME Excess Lifetime Cancer Risk Adult
PCBs Area							
Organics							
Dieldrin	0.0034	1.3E-08	3.6E-08	1.6E+01	B2	2E-07	6E-07
Total:						2E-07	6E-07

Noncarcinogenic Chemical	RME Exposure Point Concentration (ug/L)	Average Daily Dose (mg/kg-day) Child	Average Daily Dose (mg/kg-day) Adult	Adjusted RfD (mg/kg-day)	Target Organ/ Critical Effect	RME ADD:RfD Ratio Child	RME ADD:RfD Ratio Adult
PCBs Area							
Organics							
Dieldrin	0.0034	1.5E-07	8.4E-08	5E-05	Liver	3E-03	2E-03
Inorganics							
Iron	18,000 *	2.3E-03	1.2E-03	3E-01	---	8E-03	4E-03
Manganese	562 *	7.0E-05	3.9E-05	1.3E-03	CNS	5E-02	3E-02
Hazard Index:						6E-02	4E-02

CNS = Central Nervous System.
* Maximum Detected Concentration.

TABLE 3-51
EXPOSURES AND RISKS ASSOCIATED WITH INGESTION OF GROUNDWATER
BY HYPOTHETICAL FUTURE WORKERS AT OU3

FUTURE LAND-USE CONDITIONS

Carcinogenic Chemical	RME Exposure Point Concentration (ug/L)	Lifetime Average Daily Dose (mg/kg-day)	Slope Factor $(mg/kg\text{-}day)^{-1}$	Weight-of-Evidence Classification	RME Excess Lifetime Cancer Risk
PCBs Area					
Organics					
Dieldrin	0.0034	1.2E-08	1.6E+01	B2	2E-07
Total:					2E-07

Noncarcinogenic Chemical	RME Exposure Point Concentration (ug/L)	Average Daily Dose (mg/kg-day)	RfD (mg/kg-day)	Target Organ/ Critical Effect	RME ADD:RfD Ratio
PCBs Area					
Organics					
Dieldrin	0.0034	3.3E-08	5E-05	Liver	7E-04
Inorganics					
Iron	18,000 *	1.8E-01	3E-01	---	6E-01
Manganese	562 *	5.5E-03	2.4E-02	CNS	2E-01
Hazard Index:					8E-01

CNS = Central Nervous System.

* Maximum detected concentration.

TABLE 3-52
EXPOSURES AND RISKS ASSOCIATED WITH INCIDENTAL INGESTION OF SURFACE SOIL
BY HYPOTHETICAL FUTURE RESIDENTS AT OU3

FUTURE LAND-USE CONDITIONS

Carcinogenic Chemical	RME Exposure Point Concentration (mg/kg)	Lifetime Average Daily Dose (mg/kg-day) Child	Lifetime Average Daily Dose (mg/kg-day) Adult	Slope Factor (mg/kg-day)$^{-1}$	Weight-of-Evidence Classification	RME Excess Lifetime Cancer Risk Child	RME Excess Lifetime Cancer Risk Adult
PCBS Area							
Organics							
Benzo(a)anthracene	10 *	1.10E-05	5.87E-06	7.3E-01	B2	8E-06	4E-06
Benzo(a)pyrene	8 *	8.77E-06	4.70E-06	7.3E+00	B2	6E-05	3E-05
Benzo(b)fluoranthene	8.4	9.21E-06	4.93E-06	7.3E-01	B2	7E-06	4E-06
Dibenz(a,h)anthracene	0.74 *	8.11E-07	4.34E-07	7.3E+00	B2	6E-06	3E-06
Indeno(1,2,3-c,d)pyrene	0.769	8.43E-07	4.51E-07	7.3E-01	B2	6E-07	3E-07
PCB-1260	0.702 *	7.69E-07	4.12E-07	2.0E+00	B2	2E-06	8E-07
Total:						9E-05	5E-05

* Maximum detected concentration.

TABLE 3-53
EXPOSURES AND RISKS ASSOCIATED WITH DERMAL ABSORPTION OF CHEMICALS IN SURFACE SOIL
BY HYPOTHETICAL FUTURE RESIDENTS AT OU3

FUTURE LAND-USE CONDITIONS

Carcinogenic Chemical	RME Exposure Point Concentration (mg/kg)	Lifetime Average Daily Dose (mg/kg-day)		Adjusted Slope Factor (mg/kg-day)[1]	Weight-of-Evidence Classification	RME Excess Lifetime Cancer Risk	
		Child	Adult			Child	Adult
PCBS Area							
Organics							
Benzo(a)anthracene	10 *	1.21E-05	2.05E-05	7.3E-01	B2	9E-06	2E-05
Benzo(a)pyrene	8 *	9.64E-06	1.64E-05	7.3E+00	B2	7E-05	1E-04
Benzo(b)fluoranthene	8.4	1.01E-05	1.73E-05	7.3E-01	B2	7E-06	1E-05
Dibenz(a,h)anthracene	0.74 *	8.92E-07	1.52E-06	7.3E+00	B2	7E-06	1E-05
Indeno(1,2,3-c,d)pyrene	0.769	9.27E-07	1.58E-06	7.3E-01	B2	7E-07	1E-06
PCB-1260	0.702 *	5.08E-07	8.65E-07	2.2E+00	B2	1E-06	2E-06
Total:						9E-05	2E-04

* Maximum detected value.

TABLE 3-54
EXPOSURES AND RISKS ASSOCIATED WITH INCIDENTAL INGESTION OF SURFACE SOIL
BY HYPOTHETICAL FUTURE WORKERS AT OU3

FUTURE LAND-USE CONDITIONS

Carcinogenic Chemical	RME Exposure Point Concentration (mg/kg)	Lifetime Average Daily Dose (mg/kg-day)	Slope Factor $(mg/kg\text{-}day)^{-1}$	Weight-of-Evidence Classification	RME Excess Lifetime Cancer Risk Child
PCBS Area					
Organics					
Benzo(a)anthracene	10 *	1.75E-06	7.3E-01	B2	1E-06
Benzo(a)pyrene	8 *	1.40E-06	7.3E+00	B2	1E-05
Benzo(b)fluoranthene	8.4	1.47E-06	7.3E-01	B2	1E-06
Dibenz(a,h)anthracene	0.74 *	1.29E-07	7.3E+00	B2	9E-07
Indeno(1,2,3-c,d)pyrene	0.769	1.34E-07	7.3E-01	B2	1E-07
PCB-1260	0.702 *	1.23E-07	2.0E+00	B2	2E-07
Total:					1E-05

* Maximum detected concentration.

TABLE 3-55
EXPOSURES AND RISKS ASSOCIATED WITH DERMAL ABSORPTION OF CHEMICALS IN SURFACE SOIL BY HYPOTHETICAL FUTURE WORKERS AT OU3

FUTURE LAND-USE CONDITIONS

Carcinogenic Chemical	RME Exposure Point Concentration (mg/kg)	Lifetime Average Daily Dose (mg/kg-day)	Adjusted Slope Factor $(mg/kg\text{-}day)^{-1}$	Weight-of-Evidence Classification	RME Excess Lifetime Cancer Risk Child
PCBS Area					
Organics					
Benzo(a)anthracene	10 *	1.22E-05	7.3E-01	B2	9E-06
Benzo(a)pyrene	8 *	9.78E-06	7.3E+00	B2	7E-05
Benzo(b)fluoranthene	8.4	1.03E-05	7.3E-01	B2	8E-06
Dibenz(a,h)anthracene	0.74 *	9.05E-07	7.3E+00	B2	7E-06
Indeno(1,2,3-c,d)pyrene	0.769	9.41E-07	7.3E-01	B2	7E-07
PCB-1260	0.702 *	5.15E-07	2.2E+00	B2	1E-06
Total:					1E-04

* Maximum detected concentration.

TABLE 3-56
EXPOSURES AND RISKS ASSOCIATED WITH INCIDENTAL INGESTION OF SURFACE SOIL
BY HYPOTHETICAL FUTURE ENVIRONMENTAL EDUCATORS AT OU3

FUTURE LAND-USE CONDITIONS

Carcinogenic Chemical	RME Exposure Point Concentration (mg/kg)	Lifetime Average Daily Dose (mg/kg-day)	Slope Factor $(mg/kg\text{-}day)^{-1}$	Weight-of-Evidence Classification	RME Excess Lifetime Cancer Risk Child
PCBS Area					
Organics					
Benzo(a)anthracene	10 *	3.49E-06	7.3E-01	B2	3E-06
Benzo(a)pyrene	8 *	2.80E-06	7.3E+00	B2	2E-05
Benzo(b)fluoranthene	8.4	2.94E-06	7.3E-01	B2	2E-06
Dibenz(a,h)anthracene	0.74 *	2.59E-07	7.3E+00	B2	2E-06
Indeno(1,2,3-c,d)pyrene	0.769	2.69E-07	7.3E-01	B2	2E-07
PCB-1260	0.702 *	2.45E-07	2.0E+00	B2	5E-07
Total:					3E-05

* Maximum detected concentration.

TABLE 3-57
EXPOSURES AND RISKS ASSOCIATED WITH DERMAL ABSORPTION OF CHEMICALS IN SURFACE SOIL BY HYPOTHETICAL FUTURE ENVIRONMENTAL EDUCATORS AT OU3

FUTURE LAND-USE CONDITIONS

Carcinogenic Chemical	RME Exposure Point Concentration (mg/kg)	Lifetime Average Daily Dose (mg/kg-day)	Adjusted Slope Factor $(mg/kg\text{-}day)^{-1}$	Weight-of-Evidence Classification	RME Excess Lifetime Cancer Risk Child
PCBS Area					
Organics					
Benzo(a)anthracene	10 *	1.22E-05	7.3E-01	B2	9E-06
Benzo(a)pyrene	8 *	9.78E-06	7.3E+00	B2	7E-05
Benzo(b)fluoranthene	8.4	1.03E-05	7.3E-01	B2	8E-06
Dibenz(a,h)anthracene	0.74 *	9.05E-07	7.3E+00	B2	7E-06
Indeno(1,2,3-c,d)pyrene	0.769	9.41E-07	7.3E-01	B2	7E-07
PCB-1260	0.702 *	5.15E-07	2.2E+00	B2	1E-06
Total:					1E-04

* Maximum detected value.

TABLE 3-58

CUMULATIVE RISKS ASSOCIATED WITH EXPOSURES AT OU3

Receptor/Pathway	Cancer Risk	Non-cancer Hazard Index
CURRENT LAND-USE CONDITIONS		
Trespasser/Recreational User:		
PCBs Area		
Ingestion of sediment	$7x10^{-7}$	NE
Dermal absorption of sediment	$2x10^{-6}$	NE
Dermal absorption of surface water	NE	<1 ($1x10^{-3}$)
Ingestion of soil	$3x10^{-6}$	NE
Dermal absorption of soil	$2x10^{-5}$	NE
Cumulative Risk	$3x10^{-5}$	<1 ($1x10^{-3}$)
Pesticides Area		
Ingestion of sediment	$3x10^{-8}$	NE
Dermal absorption of sediment	$2x10^{-7}$	NE
Dermal absorption of surface water	NE	<1 ($2x10^{-2}$)
Cumulative Risk	$2x10^{-7}$	<1 ($2x10^{-2}$)
FUTURE LAND-USE CONDITIONS		
Worker:		
PCBs Area		
Ingestion of sediment	$2x10^{-7}$	NE
Dermal absorption of sediment	$1x10^{-7}$	NE
Ingestion of groundwater	$2x10^{-7}$	<1 ($8x10^{-1}$)
Ingestion of soil	$1x10^{-5}$	NE
Dermal absorption of soil	$1x10^{-4}$	NE
Cumulative Risk	$1x10^{-4}$	<1 ($8x10^{-1}$)
Pesticides Area		
Ingestion of sediment	$1x10^{-8}$	NE
Dermal absorption of sediment	$8x10^{-9}$	NE
Cumulative Risk	$2x10^{-8}$	NE
Environmental Educator:		
PCBs Area		
Ingestion of sediment	$6x10^{-6}$	NE
Dermal absorption of sediment	$1x10^{-5}$	NE
Dermal absorption of surface water	NE	<1 ($3x10^{-3}$)
Ingestion of soil	$3x10^{-5}$	NE
Dermal absorption of soil	$1x10^{-4}$	NE
Cumulative Risk	$1x10^{-4}$	<1 ($3x10^{-3}$)
Pesticides Area		
Ingestion of sediment	$3x10^{-7}$	NE
Dermal absorption of sediment	$1x10^{-6}$	NE
Dermal absorption of surface water	NE	<1 ($4x10^{-2}$)
Cumulative Risk	$1x10^{-6}$	<1 ($4x10^{-2}$)

TABLE 3-58

CUMULATIVE RISKS ASSOCIATED WITH EXPOSURES AT OU3

Receptor/Pathway	Cancer Risk	Non-cancer Hazard Index
FUTURE LAND-USE CONDITIONS (continued)		
Child Resident:		
PCBs Area		
Ingestion of sediment	$5x10^{-6}$	NE
Dermal absorption of sediment	$4x10^{-6}$	NE
Dermal absorption of surface water	NE	<1 ($4x10^{-3}$)
Ingestion of groundwater	$3x10^{-7}$	>1 (5)
Dermal absorption of groundwater	$2x10^{-7}$	<1 ($6x10^{-2}$)
Ingestion of surface soil	$9x10^{-5}$	NE
Dermal absorption of surface soil	$9x10^{-5}$	NE
Cumulative Risk	$2x10^{-4}$	>1 (5)
Pesticides Area		
Ingestion of sediment	$2x10^{-7}$	NE
Dermal absorption of sediment	$3x10^{-7}$	NE
Dermal absorption of surface water	NE	<1 ($5x10^{-2}$)
Cumulative Risk	$5x10^{-7}$	<1 ($5x10^{-2}$)
Adult Resident:		
PCBs Area		
Ingestion of fish (a)	$5x10^{-3}$	<1 ($4x10^{-1}$)
Ingestion of groundwater	$6x10^{-7}$	>1 (2)
Dermal absorption of groundwater	$6x10^{-7}$	<1 ($4x10^{-2}$)
Ingestion of surface soil	$5x10^{-5}$	NE
Dermal absorption of surface soil	$2x10^{-4}$	NE
Cumulative Risk	$5x10^{-3}$	>1 (2)

(a) The most conservative value for eel was used.
NE = Not Evaluated, since no chemicals in this grouping (i.e., carcinogenic/noncarcinogenic) were evaluated.

4.0 ECOLOGICAL RISK ASSESSMENT

The purpose of the ERA is to assess the potential for adverse effects to non-human receptors resulting from exposure to chemicals at of WRF. The ERA was conducted in accordance with national and regional USEPA guidance for evaluating ecological risks at hazardous waste sites (USEPA, 1989a,b, 1992a, and 1994a) and in accordance with relevant Army guidance (Wentsel et al. 1994). Consistent with this guidance, the approaches used in the ERA are similar to those used in the HHRA. The physical features of the site are first described and individual organisms, populations, or communities likely to occur at WRF are identified. The COPC are then identified along with the pathways by which ecological receptors could be exposed to chemicals. The potential toxicity of the COPC to ecological receptors selected for evaluation is then characterized. Finally, information on exposure and toxicity are combined to derive qualitative or quantitative estimates of the potential for adverse effects to ecological resources at WRF.

4.1 PROBLEM FORMULATION

The problem formulation section of the ERA evaluates available information about the site history and past land use activities, the ecological resources and COPC associated with the site, and the pathways by which ecological receptors could be exposed to these chemicals. The section concludes with the identification of the ecological resources and the endpoints selected for evaluation in the ERA.

The problem formulation section is broken down into the following sub-sections. Section 4.1.1 provides a general overview of WRF and includes a description of the topography, past and present land use patterns, contaminants known to be associated with on-site activities, and the habitats/ecological resources known or likely to occur on-site. Section 4.1.2 identifies the COPC selected for evaluation and the data groupings selected for each media. Section 4.1.3 identifies the ecological receptor species and potential exposure pathways selected for evaluation. Finally, Section 4.1.4 discusses the assessment endpoints identified for evaluation in the ERA, and the methods and/or data used for this evaluation.

4.1.1 Site Description

4.1.1.1 General Site Description and Discussion of Past On-site Activities

WRF is approximately 580 acres in size and is located in Prince William County, Virginia (Figure 2-1). It is bounded by Marumsco Creek (part of Marumsco National Wildlife Refuge) to the west and by Occoquan and Belmont bays to the south and east, respectively. Although the majority of WRF is undeveloped, residential, commercial, and industrial areas are located directly north of the installation boundary. A residential community and golf course are presently under construction (beginning in summer 1995) along the northern installation boundary.

The topography of WRF is generally flat, with a gentle slope to the south and east. The topographic high, 30 feet, occurs at the western installation boundary and Marumsco Creek shoreline. WRF lies within the western portion of the Coastal Plain Physiographic Province, approximately eight miles east of the Fall Line.

The OU3 portion of WRF(refer to Figure 2-20) consists of the Main Ditch that runs from the northern property boundary to the point where it discharges into the Occoquan and Belmont bays and the area that is located between the Main Ditch and the northern boundary of the Main Compound (portions of AREEs 11 and 17). The upper section of OU3 is comprised of two branches. The northern branch receives discharge from an area north of the facility boundary as well as runoff from on-site areas. At the time of the RI, the area to the north of WRF was being cleared of trees for the development of a golf course and private residences. The northwestern branch originates close to main entrance of the facility and receives runoff predominantly from on-site locations. The two branches converge approximately 1,000 feet to the east of the western facility boundary. Following the convergence of the north and northwestern branches, the Main Ditch travels approximately 1,500 feet to a location adjacent to the Main Compound, where it receives discharge from a ditch which drains the Main Compound area. The Main Ditch travels roughly 1,000 feet further to the east and turns abruptly to the south, where it crosses Charlie Road and ultimately discharges to the Occoquan and Belmont bays.

WRF was acquired by the US Army in 1952, prior to this the site was used primarily for agricultural purposes. WRF was used as an electronics testing facility with activities ranging from receiving and transmitting radio signals to testing the effects of electromagnetic pulses on electronic equipment. These activities required the construction and use of large antenna arrays at locations throughout the facility. Disposal of equipment and material also occurred at WRF. Section 2.2 of the FFS should be referred to for a detailed description of past on-site activities at WRF.

4.1.1.2 Description of Habitats and Wildlife at the Woodbridge Research Facility

Only approximately 24 of the 580 acres on WRF support improvements such as buildings, roads, and parking areas. The remaining 556 acres consist of undeveloped land, much of which was used during testing. The habitat surrounding OU3 consists primarily of open fields and palustrine wetlands. Woodland areas (excluding those considered wetlands) occur primarily along the western installation boundary outside of the drainage basin for the Main Ditch. A brief description of these habitats is given below, for a more detailed description please refer to the Environmental Impact Statement (EIS) (USACE, 1994).

Open Field Habitats. Open field habitats surround most of OU3 upstream of the discharge from the Main Compound area. Open field habitats consist of large areas that were kept mowed during the active life of the facility. The frequency of mowing has decreased since the facility is no longer active. Much of the open areas surrounding the drainage ditches is considered wetlands. The vegetative community of the open field areas is dominated by jointgrass (*Manisuris cylindrica*), dropseed grass (*Muhlenbergia expansa*), bush clover (*Lespedeza capitata*), white-top sedge (*Dichromena clorata*), broomsedge (*Andropogon virginicus*), and yellow foxtail (*Setaria glauca*) among others. In many of the open fields sweetgum (*Liquidambar styraciflua*) saplings occur in abundance. Several bird species are expected to use the open field habitat for feeding, nesting, or roosting. Examples of the bird species expected to occur include bobwhite quail (*Colinus virginianus*), mourning dove (*Zenaida macroura*), eastern bluebird (*Sialia sialis*), red-tailed hawk (*Buteo jamaicenis*), and a variety of finches and sparrows. Bald eagles (*Haliaeetus leucocephalus*) have been observed roosting and flying over WRF. Mammals expected to occur include groundhog (*Marmota monax*), whitetail deer (*Odocoileus virginianus*), and red fox (*Vulpes vulpes*). Other animals observed or expected to utilize the open field habitats of WRF include, snakes, turtles, and mice.

Palustrine Wetlands. Wetlands follow the Main Ditch as it flows toward the southern boundary of OU3. The wetlands consist predominantly of open wetlands, becoming increasingly forested downstream from the swale which drains the Main Compound area. The most common tree species occurring in the wetland areas are black gum (*Nyssa sylvatica*), sweet gum, red maple (*acer rubrum*), and persimmon (*Diospyros virginiana*). Understory species are dominated by northern arrowwood (*Viburnum recognitum*) and silky dogwood (*Cornus amomum*). The more open wetlands are dominated by cattail species (*Typha* spp.), marsh mallow (*Hibiscus moscheutos*), swamp rose (*Rosa palustrius*), buttonbush (*Cephalanthus occidentalis*), spatterdock (*Nuphar luteum*), soft rush (*Juncus effusus*), pickerel weed (*Pontederia cordata*), and pond lily (*Nuphar variegatum*). A variety of terrestrial animal species are expected to utilize the wetland habitats including, spotted salamander, (*Ambystoma maculatum*), green frog (*Rana clamitans melanota*), pickerel frog (*Rana palustris*), eastern box turtle (*Terrapene carolina*), eastern painted turtle (*Chrysemys picta*), northern water snake (*Nerodia sipedon*), belted kingfisher (*Ceryle alcyon*), wood duck (*Aix sponsa*), mallard duck (*Anas platyrhynchos*), American black duck (*Anas rubripes*), Canada goose (*Branta canadensis*), great blue heron (*Ardea herodias*), great egret (*Casmerodius albus*), little blue heron (*Egretta caerulea*), black-crowned night-heron (*Nycticorax nycticorax*), green heron (*Butorides striatus*), raccoon (*Procyon lotor*), whitetail deer, and beaver (*Castor canandensis*). A heron rookery exists on Mason Neck Wildlife Refuge which is across Belmont Bay from WRF. Herons from the rookery are likely to utilize WRF aquatic habitats.

The upper portion of the Main Ditch is nontidal because of the presence of the beaver dam that is located approximately 1200 feet south of Charlie Road (refer to Figure 2-22). The upper reaches of the Main Ditch, above the discharge to the Main Ditch (which includes the northern

and northwestern branches), is less than two feet wide at most locations. Below the drainage swale from the Main Compound, the ditch widens into the wetland area described above. This area supports a variety of different fish and amphibian species, in addition to the a number of different aquatic invertebrates. The fish species known to occur in these waters include bluegill (*Lepomis macrochirus*), channel catfish (*Ictalurus punctatus*), carp (*Cyprinus carpio*), American eel (*Anguilla rostrata*), and black crappie (*Pomoxis nigromaculatus*). Largemouth bass (*Micropterus salmoides*) and several species of minnows are also likely to occur in the Main Ditch.

Woodlands. As discussed above, woodland areas of WRF (excluding those considered wetlands) are located primarily along the western installation boundary along Marumsco Creek National Wildlife Refuge. The woodlands are dominated by northern red oak (*Quercus rubra*), white oak (*Quercus alba*), chestnut oak (*Quercus prinus*), Virginia pine (*Pinus virginiana*), and American Beech (*Fagus grandifolia*). Animal species expected to occur in the woodland areas include a variety of birds such as American robin (*Turdus migratorius*), hairy woodpecker (*Picoides villosus*), downy woodpecker (*Picoides pubescens*), redtail hawk, and mammals such as whitetail deer, and gray squirrel (*Sciurus carolinensis*). Because of the proximity of the woodland habitats to the Main Ditch area of OU3 and the mobility of these species, it is possible these terrestrial wildlife species also occur infrequently in the area around OU3.

Threatened and Endangered Species. A threatened and endangered species search for the WRF was requested through both the State of Virginia Department of Conservation and Recreation and the U.S. Fish and Wildlife Service Chesapeake Bay Field Office. Results of both searches indicate the presence of bald eagle (*Haliaeetus leucocephalus*) on WRF (VDCR, 1995; USFWS, 1995). Bald eagle are currently listed as federally threatened. No known bald eagle nests occur directly on WRF though a communal bald eagle roost is present on Mason Neck, located to the east of the facility. Eagles are known to frequently travel between Mason Neck and the WRF. No other species of special concern were identified in either of the searches.

4.1.2 Identification of Chemicals of Potential Concern

This section of the ERA identifies COPC for detailed evaluation in the ERA. In this section, the methodology used to select the COPC is described and the COPC are identified. Chemicals are selected for evaluation in the ERA if they (1) are presumed to be present because of past activities at the site, and (2) pose potential risks to ecological species. Chemicals associated with sampling or laboratory artifacts, or chemicals at or below naturally occurring background levels (as indicated by the reference samples) were not selected as COPC.

The following steps, which are in accordance with USEPA (1989a) guidance, were first used to summarize the analytical data for this RA:

- The samples were divided into data groupings by environmental medium and exposure area (site). The creation of these data groupings allows for the characterization of environmental conditions relevant to exposure and helps to determine exposure concentrations for target populations. A grouping of background data is used to determine if chemicals detected at a site are present at naturally occurring levels. The sample data groupings used in the ERA, including background data groupings, are described by environmental medium in the sections below.

- Sample data were compared to blank (laboratory, field, and trip) concentration data. If the chemical concentration detected in a site-related sample was less than 10 times (for common laboratory chemicals) or five times (for all other compounds) the concentration in the corresponding blank sample, the sample was considered a non-detect in accordance with USEPA (1994a) Region III guidance. The identification and validation of sampling or laboratory artifacts were performed prior to data summarization.

- As requested by USEPA (1994a) Region III guidance, the maximum concentration of a pair of duplicate or split samples (taken from the same location on the same date) was used to represent the concentration for that location. This differs from the human health RA where

the average of a pair of duplicate or split samples is used to represent the concentration at a location.

- The mean concentration of a chemical within a given medium and sample data grouping was calculated by averaging the detected concentration(s) with one-half the quantitation limit of the nondetect(s). It should be noted that when one-half the quantitation limit exceeds the maximum detected concentration in a sample grouping, the arithmetic mean could exceed the maximum detected concentration.

  Following USEPA (1994a) Region III guidance, when one-half the sample quantitation limit of a nondetect was less than the ecological criterion[1] for a chemical in a given environmental medium and the sample quantitation limit is greater than the ecological criterion, then the criterion was used as a proxy concentration for the nondetect rather than one-half the quantitation limit. If, however, the sample quantitation limit is less than the ecological criterion then one-half the sample quantitation limit was used. As a result of this procedure, a few sample quantitation limits for nondetects were replaced by the appropriate ecological criterion before calculating the mean.

- Data that were rejected by the laboratory (R qualified) were not used in the ERA.

- Frequency of detection was calculated as the number of samples in which the chemical was detected over the total number of samples collected.

Once the sampling data were grouped and summarized, chemicals were selected for further evaluation. All organic chemicals detected within a data grouping were initially identified for evaluation in the ERA. Inorganic chemicals were identified for evaluation if they were detected at concentrations greater than those representing naturally occurring background levels using the following methodology:

- To determine if detected levels of inorganic chemicals present at the site are representative of naturally occurring background levels, on-site data for each sample data grouping were statistically compared to the reference data grouping for the particular medium, where a minimum of three on-site and reference samples was available.

  When at least three samples were available for both the on-site and reference sample data sets, a two-tailed variance ratio test was first performed to determine if the variances of the on-site and reference data were similar. If the variances for a given chemical in a given medium were found to be similar, then the one-tailed pooled variance t-test was used to test for differences between on-site and reference means. If on-site and reference variances were found to differ significantly, a nonparametric test (the one-tailed Mann-Whitney test) was used to test for similarity between on-site and reference means. Inorganics that were within background levels based on these statistical tests were eliminated from further evaluation in the ERA. A detailed description of the statistical tests is presented in Zar (1984). Chemicals eliminated based on comparison to background concentrations were compared to available toxicity values in Appendix A.1.

  When less than three samples were available for both the on-site and reference sample data sets, the maximum concentration of each inorganic detected at the on-site location was compared to the maximum concentration of that inorganic chemical detected in the reference data grouping. If the maximum concentration of the inorganic chemical detected at the on-site location exceeded the maximum background concentration of that inorganic chemical or if an inorganic chemical was not detected in relevant background data grouping, then that chemical was selected as a COPC and evaluated further in the ERA. Chemicals whose maximum concentrations were less than the background value were eliminated from

[1] Chronic Federal AWQC were used as ecological criterion for chemicals in surface water. Freshwater criteria were used for surface water samples taken from the Main Ditch. The lower of NOAA ER-L and USEPA draft sediment quality criteria were used as ecological criterion for chemicals in sediments. Because analogous criterion have not been developed for chemicals in soil, one-half the sample quantitation limit was used for chemical nondetects in surface soil.

further consideration in the ERA. Chemicals eliminated based on comparison to background concentrations were compared to available toxicity values in Appendix A.1.

- Some analytes collected during the sampling events were not presented or evaluated in the ERA, including TPH (for which no toxicity criteria are available) and some water/sediment parameters (e.g., sediment moisture). Section 2.0 of the FFS should be referred to for an identification of the samples in which these analytes were analyzed for, and for a summary of these data.

Additionally, essential nutrients (i.e., calcium, magnesium, potassium, sodium) were not selected for evaluation because they are unlikely to adversely affect ecological receptors at concentrations that could occur in the environment.

Exposure point concentrations were calculated for the maximum case concentration and, where appropriate for the receptor being evaluated, the average case concentration (see Section 4.2). A summary of the chemicals identified for further evaluation in the ERA, the data groupings, and the reference sample locations are presented for each medium in the discussion below.

Chemical analytical data from sediment (0-6 inches), surface water, and fish tissue samples collected from OU3 were evaluated in the focused ERA. The results of the chemical analyses for each of these media are summarized below.

4.1.2.1 Sediment

A total of 10 sediment samples, collected during the RI from an area between the origins of the OU3 drainage on-site and an area just south of Charlie Road, were evaluated in the ERA. All samples were grouped for analyses. Five discrete background sediment samples were collected from the Mason Neck Wildlife Refuge which has not been impacted by past activities at WRF. The locations of the on-site and upgradient samples are shown in Figures 2-4 and 2-5, respectively. All sediment samples were analyzed for TCL VOCs, TCL SVOCs, pesticides/PCBs, TAL metals, PAHs, and PCTs, with the exception of RISD35, which was not analyzed for PCTs.

Chemicals detected in the sediment samples on OU3 are summarized in Table 4-1. A total of 21 organic chemicals were detected in these samples, consisting of 16 PAHs, 4 pesticides, and PCB-1260. Of the inorganic chemicals detected in sediment, only barium and lead were detected at concentrations above background and identified as COPC.

4.1.2.2 Surface Water

Surface water on-site and reference samples were collected during the RI from the same locations at which the sediment samples were collected. Accordingly, the same data groupings that were used for the sediment samples were also used for surface water for the evaluation of the data. All surface water samples were analyzed for TCL VOCs, TCL SVOCs, pesticides/PCBs, TAL metals, PAHs, and PCTs.

Chemicals detected in the surface water samples from OU3 are summarized in Table 4-2. The following inorganic chemicals were detected at concentrations above background and preliminarily identified as COPC: aluminum, barium, cadmium, chromium, copper, lead, thallium, vanadium, and zinc. Potassium was detected at concentrations above background but is an essential nutrient and unlikely to adversely affect potential ecological receptors at the detected concentrations, and therefore, not identified as a COPC.

4.1.2.3 Fish Residue

As part of the Woodbridge Site Investigation, Earth Tech was contracted by USAEC to conduct biota sampling for tissue residue analysis in late 1995. The biota sampling included fish sampling in the Main Ditch from an area immediately downstream from the location of the furthest downgradient sediment sample (see Figure 2-4).[2] Fish were collected using nets, seines, and electro-fishing gear. A

[2] Available information suggests fish were collected predominantly from a location upstream of the beaver dam on the Main Ditch, though it is possible that some fish were collected from below the dam.

detailed description of the fish sampling program along with an identification of each sample/test location is presented in Appendix B. All fish samples were analyzed for TCL pesticides, PCBs, PCTs, lead, and mercury.

The results of the whole body fish tissue residue analyses are summarized in Table 4-3 as both nonlipid-adjusted whole body tissue concentrations and lipid-adjusted concentrations.[3] Both whole body and fillet samples were collected from the Main Ditch; however, only the wholebody data was summarized in Table 4-3 because those results are the most applicable to the ERA. Furthermore, the nonlipid-adjusted concentrations were the focus of the present assessment because they were the most applicable to the exposure pathways evaluated and toxicity values used in the present assessment. Accordingly, only the nonlipid-adjusted concentrations were summarized in the text below and evaluated in the ERA.

As shown in Table 4-3, DDT metabolites were detected in all of the fish species collected from the Main Ditch. The highest concentrations of both DDD and DDE (325 µg/kg and 167 µg/kg wet weight, respectively) were detected in carp, while DDT metabolite concentrations were below 85 µg/kg in all other fish species. Chlordane (detected as alpha- and gamma-chlordane) was also detected in carp (concentrations up to 9.97 µg/kg and 5.85 µg/kg wet weight, respectively) and eel (concentrations up to 8.25 µg/kg and 2.31 µg/kg wet weight, respectively), but was not detected in either crappie or sunfish. PCB-1260 was detected in all of the fish and eels, with the highest concentration of 1,090 µg/kg (wet weight) PCB-1260 detected in eels. Mercury was detected in crappie, eel, and sunfish at concentrations of up to 0.207 µg/kg wet weight in crappie.

4.1.3 Identification of Exposure Pathways and Receptors for Analysis

In this section of the ERA, the potential pathways by which ecological resources may be exposed to the COPC at WRF are discussed. Exposure pathways were identified based on the consideration of (1) the source/mechanism of chemical release; (2) the medium (or media) of chemical transport; (3) the point of potential contact by the receptor organism; and (4) the route of exposure at the contact point. Potentially complete exposure pathways and potential receptor groups were identified for evaluation in the ERA based on consideration of the available habitat, and the type, extent, magnitude, and location of potential chemical contamination.

As previously discussed (Section 4.1.1.2), a variety of different plant, wildlife species, and aquatic life are associated with OU3. Figure 4-1 provides a conceptual model of the primary on-site sources of contamination and the potential pathways by which ecological receptors could contact these sources. Table 4-4 provides a more detailed description of the potential exposure pathways by which potential ecological receptors could be exposed to COPC at OU3 and identifies, in general terms, the pathways selected for evaluation in the ERA. A brief rationale for the selection/exclusion of each potentially complete exposure pathway is also summarized in this table. The following sections provide a more detailed discussion and evaluation of the pathways by which potential receptors could be exposed to COPC in surface water and sediment and discusses the exposure pathways selected for evaluation.

4.1.3.1 Aquatic and Terrestrial Plants

Aquatic and terrestrial plants are important components in any ecosystem because they provide food and cover for many wildlife species. WRF supports a variety of different plant species characteristic of both upland and wetland areas.

Aquatic and wetland plants may be exposed to chemicals in surface water or sediment. Terrestrial plants adjacent to the Main Ditch also may be exposed to chemicals in sediment and/or mobilized in surface water. However, very little information is available to evaluate exposures via foliar uptake or via contact with surface water or sediment. Accordingly, this potential exposure pathway was not evaluated in the ERA.

[3] Whole body fish tissue residue data (both whole body tissue concentrations and lipid-adjusted concentrations) is summarized in relation to body size in Appendix A.2.

4.1.3.2 Terrestrial Wildlife

Terrestrial wildlife occurring at WRF may be exposed to COPC in the Main Ditch by several pathways, including (1) the ingestion of contaminated sediment or food while foraging or grooming; (2) the ingestion or dermal absorption of chemicals from surface water; and (3) the dermal absorption of chemicals from sediment.

Among these potential exposure pathways, the greatest potential for exposure to chemicals is likely to result from the ingestion of chemicals that have accumulated in the food. This conclusion is based on both the potential for some chemicals to accumulate to higher concentrations in food than in the abiotic media from which they originate and on the relatively high ingestion rate of food as compared to surface soil. Accordingly, the potential for the exposure of terrestrial wildlife to chemicals in food was considered for evaluation.

Both organic and inorganic chemicals detected in sediment and surface water were reviewed for their potential to accumulate in aquatic and/or terrestrial food webs.[4] Chemicals having a bioconcentration factor (BCF) of greater than 300 or, in the case of organics, a octonal/water partition coefficient (expressed as log Kow)[5], of greater than three were initially considered for evaluation based on USEPA (1989a) guidance. Based on the results of this screen, chemicals identified as having the greatest potential to accumulate are summarized below.

> *Sediment:* The organic chemicals chlordane, DDD, PAHs, and PCB-1260 were detected in OU3 and have the potential to accumulate in the aquatic food web based on the parameters outlined above. However, if PAH accumulation is occurring, it would be limited to aquatic invertebrates and plants as PAHs are metabolized by most higher level species. Furthermore, chlordane and DDD were detected at only two sample locations in locations sampled in OU3 and the potential for accumulation is, therefore, likely to be limited. However, because of chlordanes' and DDDs' potential to accumulate, these compounds were considered further in the ERA. No inorganic chemicals which have the potential to accumulate were detected in sediment.
>
> *Surface Water:* No organic chemicals detected in surface water have the potential to accumulate in the aquatic environment. Cadmium and zinc, both of which have BCFs greater than 300 for some aquatic species, were also detected in surface water at concentrations above background. However, cadmium and zinc were detected at concentrations less than chronic federal AWQC, therefore, it is reasonable to conclude that these compounds would not accumulate in the aquatic environment at the detected concentrations. Accordingly, no inorganic chemicals in surface water are likely to accumulate in the aquatic environment.

After the chemicals that could accumulate in the terrestrial environment from sediment (PCB-1260, and to a lesser extent chlordane, DDD, and PAHs) were identified, the possible pathways by which receptor species could be exposed where evaluated. Emphasis was placed on higher trophic-level species because of the potential for bioaccumulation in the food web prior to the exposure of these receptors. To identify potentially impacted species, the feeding guilds of the mammals and birds known to occur at WRF were reviewed to identify the possible dietary routes by which mammals and birds could be exposed to bioaccumulative chemicals. A summary of the feeding guilds identified for avian species and mammals known to occur at WRF is presented in Tables 4-5 and 4-6, respectively, along with a list of representative species. The tables also summarize the exposure routes and species selected for evaluation in the OU3 ERA and provide a brief rationale for the selection/exclusion of each potentially complete exposure route. The following section provides a more detailed discussion of the information provided in these tables.

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[4] Wildlife could be affected by the accumulation of chemicals from surface soil; however, only sediment and surface water samples were evaluated in the OU2 investigation and potential exposure pathway(s) originating from soil were not considered in the present assessment.

[5] The octanol/water partition coefficient of an organic chemical characterizes the propensity of a chemical to partition into the lipid fraction of an organism, and thus, the potential for a chemical to bioaccumulate in an organism.

Exposure from Accumulation in the Aquatic Food Web. Birds and small mammals could be exposed to chemicals at WRF via the ingestion of aquatic life that have accumulated chemicals and this exposure pathway is potentially complete because of the presence of bioaccumulative compounds in sediment. As previously discussed, none of these chemicals were detected in surface water, and this media does not represent a significant exposure pathway.

The predominant food sources for birds and small mammals from the water bodies on and around WRF are likely to consist of aquatic invertebrates and fish. With the exception of PAHs, fish are likely to have the greatest potential to accumulate chemicals from sediment into the aquatic food web and represent an important potential exposure pathway to higher level receptors for the following reasons. First, fish represents a high trophic-level species in the aquatic environment at WRF. Furthermore, fish are an important food source for a number of terrestrial predators and represent a viable exposure pathway. Finally, fish have the potential to accumulate all of the bioaccumulative COPC, with the exception of PAHs, which are typically metabolized by fish. Accordingly, fish were selected to evaluate the potential for chlordane, DDTr, and PCBs to accumulate from sediment to higher trophic level species.

Heron were selected as an avian receptor species for evaluating potential adverse effects to birds from the ingestion of fish. Heron were selected for evaluation because a large proportion of their diet is comprised of fish. Furthermore, a heron rookery is present on Mason Neck Wildlife Refuge located immediately across Belmont Bay and within approximately two miles of WRF, and heron have been observed regularly foraging in the water bodies on WRF. A number of small mammals (e.g., mink, raccoon, shrew) are also known to occur on WRF and were considered for evaluation in the ERA. Mink were selected for evaluation because they ingest fish and are known to be extremely sensitive to PCBs, and thus, represent a sensitive indicator of the potential for adverse effects to piscivorous small mammals.

In addition to the ingestion of chemicals from fish and aquatic invertebrates, heron and mink could be exposed to chemicals from the ingestion of sediment, surface soil, and surface water while foraging or grooming. Based on the foraging habits of these species, sediment ingestion is likely to be much greater than soil and this potential exposure pathway was also selected for evaluation. None of the potentially bioaccumulative chemicals discussed above were detected in surface water, and this medium does not represent a significant exposure pathway for these chemicals.

Aquatic invertebrates also have the potential to accumulate chlordane, DDD, and PCB-1260 from sediment (USEPA, 1980). Additionally, PAHs, which are metabolized in fish, readily accumulate in aquatic invertebrates. Further, aquatic invertebrates are likely to represent an important food source for a variety of terrestrial wildlife species (e.g., dabbling ducks, raccoons). Of the aquatic invertebrates occurring on WRF, freshwater clams, which were observed in the lower reaches of the Main Ditch, are likely to comprise some of the greatest biomass of the organisms in sediment and represent an important potential exposure pathway. Accordingly, the ingestion of aquatic invertebrates was selected as a potential exposure route for the evaluation of potential adverse effects to terrestrial species from the accumulation of the bioaccumulative COPC. However, the evaluation of the potential for adverse effects to terrestrial wildlife from the ingestion of aquatic invertebrates will be evaluated in the site wide ERA instead of the OU3 evaluation.

Aquatic plants, though potentially a route of exposure for herbivorous species (e.g., dabbling ducks), are unlikely to represent an important route of exposure to these species given the more limited potential of these chemicals to accumulate in plant material.

4.1.3.3 Aquatic Life

Aquatic life could potentially be exposed to chemicals in OU3 by direct contact with contaminated water and sediment, respiration of chemicals in water and sediment, and ingestion of contaminated sediments and food. Aquatic life also could be exposed to chemicals via the ingestion of chemicals that have accumulated in the food web. As discussed earlier, the potential for adverse effects to terrestrial life from the ingestion of chemicals in aquatic life was selected for evaluation in the ERA.

Potential risks to aquatic life were evaluated in the Risk Characterization section (Section 4.4) of the ERA by comparing concentrations of the COPC identified in surface water and sediment to applicable toxicity values derived in the Ecological Effects Assessment section (Section 4.3) of the ERA. Because the toxicity data being used in the ERA were designed to evaluate the potential for adverse effects to aquatic communities, no specific aquatic species were selected for evaluation and the assessment evaluated the potential for adverse effects to the overall aquatic community.

4.1.4 Identification of Assessment and Measurement Endpoints

As discussed earlier, the potential for adverse effects to ecological resources is dependent on the ecological receptor species and chemicals present on the site, and the pathways by which the ecological resources could be exposed to the COPC. Section 4.1.1 preliminarily identified ecological resources occurring on the site that could be adversely affected by the presence of chemicals. Section 4.1.2 preliminarily identified the COPC present in each of the on-site media. Finally, Section 4.1.3 preliminarily identified the potential exposure pathways by which ecological receptors could be exposed to COPC, based on information about the presence of ecological resources on site and on information about the presence of COPC in each sampled environmental media. This section of the report summarizes the specific ecological parameters for each of the evaluated receptors by identifying the assessment endpoint, the hypothesis being tested in the investigation, and measurement endpoints selected for the evaluation of the assessment endpoints.

Assessment endpoints are defined as the ecological effects in the receptor species selected for evaluation. The evaluation of the potential for ecological effects to occur is one factor in the decision making process regarding the need for further investigation and/or remediation (Suter, 1993). For example, the reproductive capability of the receptor species and/or population may be an assessment endpoint selected for evaluation. Measurement endpoints are the outcomes of the methods or means by which the assessment endpoints are approximated or represented (Suter, 1993). Measurement endpoints are generally surrogates for assessment endpoints and are necessary because, in most cases, assessment endpoints cannot be directly measured or observed. Typically, the measurement endpoints are the result of or outcome of the field and/or laboratory methods used to evaluate the assessment endpoints. For example, the measurement endpoint for the evaluation of the potential for adverse effects to receptor organisms, populations, and/or communities may be the concentration of a chemical measured in an abiotic media to which the receptor species could be exposed compared to an applicable toxicity value and/or may be the results of a fish population survey from the area of concern.

The assessment and measurement endpoints selected for evaluation in the OU3 ERA are summarized in Table 4-7. In addition, Table 4-7 states formal testable hypotheses for each of the assessment endpoints selected for evaluation.

4.2 EXPOSURE ASSESSMENT

The purpose of the exposure assessment is to identify the concentration and/or dose of the COPC to which ecological resources selected for evaluation in the ERA could be exposed. The following sections discuss the evaluation of exposure and identify the exposure concentrations selected for the evaluation of potential adverse effects to each of the ecological receptor groups/organisms selected for evaluation.

4.2.1 Terrestrial Wildlife

The following discussion presents the methods used to calculate the potential ingestion of chemicals by heron and mink via the ingestion of fish and sediment. The equations presented below were derived based on equations presented in USEPA (1989a).

The following equation was used to calculate the dose of chemicals that a heron or mink would be expected to obtain from the ingestion of fish:

$$Dose_{fish} = FI * C_{diet}$$

where:

$Dose_{fish}$ = amount of chemical ingested per day via the ingestion of fish (mg/kg bw-d);

FI = food ingestion rate (kg/kg bw-d);

C_{diet} = estimated COPC concentration in diet (mg/kg).

A food ingestion rate (FI) of 0.18 kg/kg bw-d reported by Kushlan (1978) for great blue heron was used in the ERA. A FI of 0.22 kg/kg bw-d estimated in USEPA (1993) using an equation by Nagy (1978) and body weight reported by Mitchell (1961) for mink was used in the ERA.

The estimated dietary concentration (C_{Diet}) was calculated using the following equation:

$$C_{diet} = P_f * C_f$$

where:

P_f = proportion of diet consisting of fish (unitless)

C_f = estimated concentration of COPC in fish (mg/kg).

The proportion of the diet (P_f) consisting of fish was based on information obtained from the scientific literature. Alexander (1977) reported a year-round P_f of 98% for heron living near a river and 61% for mink living near a stream. For both heron and mink it was assumed that 100% of the fish ingested are from the sampled area of the Main Ditch. This assumption is conservative and may lead to an overestimate of potential risks because both species are likely to obtain some food from areas outside of OU3, and in the case of heron, outside the bounds of WRF.

Chemical concentrations measured in whole body fish tissue were used to estimate C_f.

The average concentration of each chemical detected in all sampled fish (see Table 4-3) was used in the model because it was determined to most accurately estimate the exposure of these predators foraging in the environment.

In addition to the ingestion of chemicals accumulated in fish, heron and mink also may be exposed to chemicals through the inadvertent ingestion of sediment while foraging or grooming. The following equation was used to calculate the dose of chemical these species would be expected to obtain from the ingestion of sediment:

$$Dose_{sediment} = SI * C_{sediment}$$

where:

$Dose_{sediment}$ = amount of chemical ingested per day from sediment (mg/kg bw-d);

SI = sediment ingestion rate (kg/kg bw-d);

$C_{sediment}$ = average COPC concentration in sediment (mg/kg).

Based on percent dietary soil/sediment ingestion presented by Beyer et al. (1994), it was assumed that 8.2% of the total mass of a heron's diet and 9.4% of the total mass of a mink's diet is sediment. The percent sediment ingestion was multiplied by the food ingestion rates (FI) presented earlier for these species to estimate sediment ingestion rates (0.015 kg/kg bw-d for heron and 0.02 kg/kg bw-d for mink). As for the estimation of exposure to chemicals in fish tissue, the average chemical concentration was used for $C_{sediment}$.

The total dietary exposure levels for mink and heron to DDTr was determined using the following equation:

$$Dose_{total} = Dose_{fish} + Dose_{sediment}$$

Using the above equation, the estimated total dose of chemicals from the ingestion of fish tissue and sediment was determined. The estimated total dose is presented in Section 4.4.1 where it is compared to toxicity values derived in Section 4.3.1 for mink and heron.

4.2.2 Aquatic life

4.2.2.1 Sediment

Chemical concentrations measured in sediment from locations towards the upper portions of the Main Ditch were used to evaluate the potential for adverse effects to benthic organisms. Maximum chemical concentrations measured in sediment samples are given in Table 4-1 for OU3. The maximum concentration was used for the initial evaluation because, based on the relative immobility of most aquatic invertebrates, exceedence of a toxicity value at a sample location indicates the potential for adverse effects at that location. The potential for adverse effects at the community level can then be evaluated by identifying the overall proportion of sample locations where the toxicity value is exceeded.

4.2.2.2 Surface Water

Chemical concentrations measured in surface water from OU3 were used to evaluate the potential for adverse effects to aquatic life. Average concentrations measured in surface water samples are given in Table 4-2. Based on the mobility of most aquatic species and the transient nature of surface water, particularly flowing water, the average chemical concentrations measured in the surface water samples best represent the exposure concentrations to which the aquatic life in a water body could be exposed and were selected for evaluation.

4.3 ECOLOGICAL EFFECTS ASSESSMENT

4.3.1 Terrestrial Life

Toxicity criteria have not been developed by USEPA for terrestrial species. Consequently, toxicity data in the scientific literature were reviewed to characterize the toxicity of the COPC selected for evaluation. Toxicity values selected for the evaluation of the potential for adverse effects are referred to as toxicity reference values (TRVs) and represent concentrations of the COPC that are protective of the ecological receptors being evaluated.

As previously discussed, risks to heron and mink from the ingestion of fish and sediment were selected for evaluation. Toxicological benchmarks derived by Opresko et al. (1994) were used to evaluate the potential for adverse effects to the receptors of concern.

4.3.2 Aquatic Life

4.3.2.1 Surface Water

Federal AWQC were developed by USEPA for the protection of aquatic life and were used to assess potential impacts to aquatic species. Both chronic and acute freshwater AWQC were used to evaluate the potential for adverse effects to aquatic life. Acute AWQC were used in the comparison because a storm event was occurring at the time of sampling and there is the potential for a "pulse" of chemicals to have been released in surface water as a result of increased surficial runoff. Chronic freshwater AWQC also were used to evaluate the potential for adverse effects to aquatic life in case the detected concentrations are indicative of longer-term exposure. For hardness-dependent criteria, the average hardness value measured in the ditches during the RI was 31.2 mg/l as $CaCO_3$ and was adjusted upward to 50 mg/l as $CaCO_3$ to be consistent with the minimum hardness value for which AWQC could be derived. In the absence of AWQCs, proposed criteria and toxicity data from the literature were used.

4.3.2.2 Sediment

Two sources of toxicity data were used to identify the potential for chemicals in sediment to cause adverse effects to benthic communities. The USEPA Office of Water has developed draft sediment quality criteria (SQC) that represent the Agency's best recommendation of the concentrations of a substance in sediment that will not unacceptably affect benthic organisms (USEPA 1993). The methodology used to generate the proposed criteria is called the equilibrium partitioning (EqP) approach and applies only to non-ionic organic chemicals. Draft freshwater sediment criteria have recently been developed for three PAHs (fluoranthene, phenanthrene, and acenaphthene) and two pesticides (aldrin and dieldrin). In addition to the draft criteria, Effects Range-Low (ER-L) and Effects Range-Median (ER-M) values reported in Long and Morgan (1990) and subsequent updates in Long et al. (1995) were employed as TRVs to determine if chemicals in the sediments are likely to impact aquatic communities. Effects range values were derived from the compilation of the available sediment toxicity data for a chemical. The ER-L value is equivalent to the lower 10th percentile of the available toxicity data, which is estimated to be the approximate concentration at which effects are likely to occur in sensitive life stages and/or species. The ER-M value is equivalent to the median of the available toxicity data, which is estimated to be the approximate concentration at which effects are likely to occur in most species.

Available USEPA EqP draft criteria and ER-L/ER-M values were used to evaluate the potential for adverse effects to benthic communities. In the case where both USEPA EqP draft criteria and ER-L/ER-M values are available for a chemical, the lower of the two values was used to conservatively evaluate the potential for adverse effects to benthic communities. For these chemicals, freshwater EqP draft criteria were compared to the ER-L/ER-M values used to evaluate the potential for adverse effects to aquatic life in OU3. In the absence of the above guidelines, available toxicity values from the scientific literature were used as TRVs.

4.4 RISK CHARACTERIZATION

In this section of the ERA, the potential exposure concentrations derived in Section 4.2 are compared with the TRVs derived in Section 4.3 to evaluate the potential for adverse effects to ecological resources from exposure to the COPC.

Estimated exposure concentrations for the COPC are compared to TRVs by creating a ratio of the estimated exposure concentration to the TRV. This ratio is termed the Environmental Effects Quotient (EEQ). If the EEQ is less than 1.0 (indicating the exposure concentration is less than the TRV) then adverse effects are considered unlikely. If the EEQ is equal to or greater than 1.0 (indicating the exposure concentration is greater than the TRV), there is a potential for adverse effects to occur. The confidence level of the conclusion increases as the magnitude of the ratio departs from 1.0. For example, there is greater confidence in a risk estimate where the EEQ is 0.1 or 10, than in a EEQ which is closer to 1.0. The uncertainties associated with the risk estimates are briefly discussed below and are discussed in greater detail in Section 4.5.

4.4.1 Terrestrial Wildlife

Chemicals having the potential to bioaccumulate were detected in the sediment of OU3 and there is the potential for chemicals to accumulate in the aquatic environment. No chemicals having the potential to accumulate were detected in surface water, though it is expected that some fraction of the chemicals detected in sediment are partitioning to the water column, presumably at concentrations below the detection limits. The potential for terrestrial wildlife to be adversely affected by the ingestion of chemicals accumulated in the aquatic food web was evaluated in this section.

As discussed in Section 4.1.4, the potential for great blue heron and mink to be adversely affected from the ingestion of fish was selected for evaluation. The potential for adverse effects to terrestrial wildlife was evaluated on a chemical-by-chemical basis by:

- comparing chemical concentrations measured in fish tissue collected on-site and modeled ingestion estimates to literature-based toxicity values;

- comparing chemical concentrations detected in whole body fish samples tissue collected on site to chemical concentrations detected in whole body fish samples tissue collected from areas outside the influence of WRF;
- evaluating each chemical's occurrence in OU3 and in other on-site media; and, as needed,
- evaluating the life history characteristics of fish species in relation to the potential for chemical accumulation.

Table 4-8 compares the total dose of each chemical of potential bioaccumulative concern (calculated using the equations presented in Section 4.2.1) to the TRVs identified in Section 4.3.1. Figures 4-2 through 4-6 compare the concentrations of chemicals of bioaccumulative concern detected in whole body fish tissue collected from the Main Ditch to chemical concentrations detected in whole body fish tissue collected both locally and nationally. Fish were collected locally from Neabsco Creek, Farm Creek, Gunston Cove, Accotink Bay, and Pohick Bay as part of investigations designed to collect baseline data about the contaminant status of these areas (Block 1990, Pinkney et al. 1995). All of these water bodies are within highly urbanized watersheds. Catfish and largemouth bass were collected locally to represent both benthic-dwelling and predatory species from local water bodies because these species have some of the greatest potential to accumulate chemicals from the environment. Data from whole body fish tissue collected as part of the National Contaminant Biomonitoring Program (NCBP) and reported in Schmitt et al. (1990) were used for the comparison to national concentrations. The objective of the latter program was to identify chemical concentrations in a variety of different predatory and benthic-dwelling fish species collected nationally. The local and national accumulation data is intended to provide a frame of reference concerning the chemical concentration a terrestrial predator might be exposed to at on and off-site locations. It should be recognized, however, there are limitations associated with the use of the off-site data. For example, accumulation levels will vary dramatically with many factors including the species, size, and reproductive condition of the fish being sampled. As already stated above, bass and catfish have some of the greatest potential to accumulate chemicals from the environment and the accumulation potential of these species is likely to be greater than for the species collected in the Main Ditch at OU3. Accordingly, the accumulation data should not be used as a direct comparison for accumulation at on and off-site locations, but instead, should only be used to place the on-site data into a regional and national perspective.

The following sections use the above information to evaluate the potential for adverse effects to great blue heron and mink from each of the chemicals detected in whole body fish tissue samples.

Chlordane. As previously discussed, alpha- and gamma-chlordane were detected at two locations in sediment collected from the upper reaches of the OU3 drainage (RISD 27 and 28) and could be accumulating in fish tissue from on-site locations. The EEQ for both mink and great blue heron from the ingestion of chlordane in fish and sediment is less than one (see Table 4-8) and based on these results, it is reasonable to conclude that mink and great blue heron will not be adversely affected by the ingestion of chlordane in fish and sediment. Furthermore, chlordane was only detected in the area towards the upper reaches of OU3 and was not detected in sediment or surface water at locations where fish occur in OU3. Finally, the concentrations of alpha- and gamma-chlordane detected on-site were below those detected in either catfish or bass collected from local areas and below concentrations detected in fish species collected as part of the NCBP (see Figures 4-2 and 4-3) suggesting that potential predators could be exposed to chlordane at both off-site and on-site locations, and in some cases, to potentially higher concentrations at off-site locations.

DDT/DDD/DDE. DDD was detected at two locations in the sediment of OU3 (RISD 27 and 35) and could be accumulating in fish tissue from on-site locations. The EEQ for mink from the ingestion of DDT compounds in fish and sediment is less than one (see Table 4-8). Based on these results, it is reasonable to conclude that mink will not be adversely affected by the ingestion of DDT compounds in fish and sediment. The EEQ for great blue heron from the ingestion of DDT compounds in fish and sediment is 49.9. These results indicate the potential for adverse effects to great blue heron from the presence of DDT compounds in fish and sediment. However, the average concentrations of DDD detected in all fish species collected

from the Main Ditch were below those detected in either catfish or bass collected from local areas and below those detected in fish species collected as part of the NCBP (see Figure 4-4) suggesting that potential predators could be exposed to DDD at both off-site and on-site locations, and in some cases, to potentially higher concentrations at off-site locations.

Heptachlor. Heptachlor was not detected in surface water or sediment at any sample location in OU3, or in the surface soil of the drainage basin surrounding the Main Ditch. Further, the EEQ for mink from the ingestion of heptachlor in both fish and sediment is less than one (see Table 4-8). Based on these results, it is reasonable to conclude that mink will not be adversely affected by the ingestion of heptachlor in fish and sediment. Toxicity values could not be found in the scientific literature for great blue heron and the potential for heptachlor to adversely affect this species could not be evaluated. Heptachlor was not analyzed for in fish tissue samples collected as part of the regional sampling or the NCBP.

PCB-1260. As previously discussed, PCB-1260 was detected in sediment at all sample locations below the swale which discharges to OU3 from the former oil/water separator and former washrack (RISD 31 through 35) and could be accumulating in fish tissue from on-site locations. However, the EEQ for both mink and great blue heron from the ingestion of PCB-1260 in fish and sediment is less than one (see Table 4-8) and, based on these results, it is reasonable to conclude that mink and great blue heron will not be adversely affected by the ingestion of PCBs in fish and sediment. Because of its prevalence in sediment, the concentrations of PCB-1260 detected in the fish tissue are likely to be, at least in part, attributable to the PCB-1260 detected in in samples collected from the upper reaches of the OU3 drainage. It should be noted, average PCB-1260 concentrations detected in catfish from the regional locations were less than those detected in benthic species collected from on-site locations (eel and carp) while the average PCB-1260 concentrations detected in all species at on-site locations were greater than the geometric mean concentrations detected in fish species collected as part of the NCBP (Schmitt et al. 1990) (see Figure 4-5).

Mercury. The EEQ for mink from the ingestion of mercury in fish and sediment is less than one (see Table 4-8). Based on these results, it is reasonable to conclude that mink will not be adversely affected by the ingestion of mercury in fish and sediment. The EEQ for great blue heron from the ingestion of mercury in fish and sediment is 5.8. These results indicate the potential for adverse effects to great blue heron from the presence of mercury in fish tissue. However, several factors must be considered when interpreting these results. First, mercury was not detected in the sediment and surface water in OU3. Further, the arithmetic mean mercury concentrations detected in all species collected from on-site locations remained below the average concentrations detected in fish sampled regionally (Block 1990, Pinkney et al. 1995) and below the geometric mean concentrations detected in fish sampled as part of the NCBP (Schmitt et al. 1990), respectively (see Figure 4-6). Although definitive statements cannot be made about mercury based on the number of on-site samples taken, these results suggest the mercury detected in fish tissue may not be originating from OU3. Furthermore, these data suggest potential predators could be exposed to elevated mercury concentrations at both off-site and on-site locations, and in some cases, to potentially higher concentrations at off-site locations.

Summary and Discussion of Wildlife Results. The results of the food web model indicate that mink are unlikely to be adversely affected by the ingestion of chlordane, heptachlor, or PCB-1260 in fish tissue while great blue heron are unlikely to be adversely affected by the ingestion of chlordane or PCB-1260 in fish tissue.[6] The results of the food web model also indicate mink are unlikely to be adversely affected by the ingestion of DDT compounds and mercury in fish tissue. The model does, however, suggest there is the potential for adverse effects to great blue heron from the ingestion of DDT compounds and, to a lesser extent, to great blue heron from the ingestion of mercury in fish tissue (EEQs of 49.9 for DDT compounds and 5.8 for mercury, respectively). However, the average concentrations of DDD detected in all fish species collected

[6] Toxicity values could not be found in the scientific literature to evaluate the potential for heptachlor to adversely affect great blue heron.

from the Main Ditch were below those detected in either catfish or bass collected from local areas and below those detected in fish species collected as part of the NCBP (see Figure 4-4) suggesting potential predators could be exposed to DDD at both off-site and on-site locations, and in some cases, to potentially higher concentrations at off-site locations. As discussed above, mercury was not detected in the sediment and surface water at any location in OU3. Furthermore, the arithmetic mean concentrations of mercury detected in all fish species collected from on-site locations remained below the average concentration detected in fish sampled regionally (Block 1990, Pinkney et al. 1995) and below the geometric mean concentrations detected in fish sampled as part of the NCBP (Schmitt et al. 1990). These results suggest the mercury detected in fish tissue may not be originating from OU3 and suggest, once again, that potential predators could be exposed to elevated mercury concentrations at both off-site and on-site locations.

4.4.2 Aquatic Life

4.4.2.1 Sediment

In this section of the ERA, the average (where applicable) and maximum concentrations of the COPC in the surface water of the OU3 are compared to the available toxicity values. The comparisons are shown in Table 4-9 and discussed below. Concentrations of all chemicals exceeding the available toxicity guidance values are plotted for each sample location in Appendix A.3.

Summary of Sediment Results. Sixteen PAHs, three pesticides, and one PCB were detected in the sediment collected from OU3. With the exception of dibenzo(a,h)anthracene, the maximum concentrations of all PAHs exceeded the ER-Ls (EEQs ranging from 1.3 for fluoranthene to 81.9 for acenapthene) or other available toxicity values (EEQ of 1.1 for indeno(1,2,3-c,d)pyrene and 1.4 for benzo(b)fluoranthene). However, only the maximum concentrations of acenapthene, 2-methylnaphthalene, and naphthalene exceeded the ER-M (EEQ ranging from 1.4 for naphthalene to 2.7 for 2-methylnaphthalene). The maximum concentrations of the pesticide chlordane (total), its constituent alpha- and gamma-chlordane, and DDD also exceeded both the ER-Ls (EEQs ranging from 12 for DDD to 526 for chlordane) and ER-Ms (EEQs ranging from 1.2 for DDD to 43.8 for chlordane[total]. PCB-1260 was also detected at a maximum concentration above the available toxicity value (EEQ of 1,208).

Barium and lead were detected at concentrations above background and identified as COPC. The maximum concentration of lead just exceeded the ER-L (EEQ of 1.8), but remained below the ER-M. No applicable toxicity value could be found in the scientific literature for barium and the potential for this chemical to adversely affect benthic-dwelling organisms could not be evaluated.

The results of the above comparisons indicate the potential for adverse effects to aquatic life from the presence of several organic compounds in sediment. Of the organic chemicals detected in sediment, PCB-1260 has the greatest potential to adversely affect benthic organisms. PCB-1260 was detected in sediment at the highest concentrations relative to the available TRVs. Furthermore, PCB-1260 was detected at all locations downgradient of the discharge ditch from the former oil/water separator and the former wash rack (RISD 31 through 35; see Appendix A.3).

The pesticides chlordane and DDD also have the potential to adversely affect aquatic life. Both compounds had maximum concentrations exceeding the ER-L and ER-M. However, both compounds were detected at only two of ten sample locations: chlordane was detected at RISD27 and 28 while DDD was detected at RISD27 and 35 (see Appendix A.3). Accordingly, if adverse effects are occurring as a result of pesticides, the effects would be expected to occur at only a limited number of locations.

As discussed above, sixteen PAHs were detected in sediment. With the exception of naphthalene and phenanthrene, PAHs were detected at concentrations above the available toxicity values in no more than two of the ten sample locations. Furthermore, with the exception of four PAHs (acenapthene, indeno(1,2,3-c,d)pyrene, 2-methylnaphthalene, and naphthalene), the detected PAHs consistently occurred at concentrations below the available ER-M values

suggesting that adverse effects, if occurring, would be limited predominantly to sensitive benthic organisms and/or life stages.

Lead was detected at concentrations just above the ER-L (EEQ of 1.8), and there is also a very limited potential for adverse effects to sensitive benthic organisms from the presence of lead in sediment. There is some uncertainty associated with the potential for barium to adversely affect benthic organisms as applicable toxicity values could not be found for this chemical.

4.4.2.2 Surface Water

In this section of the ERA the arithmetic mean concentrations of the COPC in the surface water of OU3 are compared to available TRVs. The comparisons are shown in Table 4-10 and discussed below. Concentrations of all chemicals exceeding the available toxicity guidance values are plotted in Appendix A.4 for each sample location.

Fluoranthene, the only organic chemical detected in surface water, was detected at a maximum concentration less than the chronic toxicity value and it is reasonable to conclude this chemical will not adversely affect aquatic life. The inorganic chemicals aluminum, barium, cadmium, chromium, copper, lead, thallium, vanadium, and zinc were detected at concentrations above background and were identified as COPC. Of these chemicals, the average concentrations of aluminum, barium, copper, lead, and vanadium exceeded the available chronic toxicity values (EEQs ranging from 1.1 for copper to 150.6 for aluminum), while only the average concentration of aluminum exceeded the acute toxicity value (EEQ of 17.5).

The above comparison indicates there is the potential for adverse effects to aquatic life from the presence of several inorganic chemicals in the surface water of OU3. A number of mean concentrations of inorganic chemicals exceeded the chronic toxicity values (aluminum, barium, copper, lead, and vanadium), while aluminum concentrations exceeded the acute toxicity value. Among these inorganic chemicals, aluminum consistently exceeded both toxicity values to the greatest extent (see Appendix A.4). However, available information suggests the chemicals detected in surface water are unlikely to be originating from on-site locations. As discussed in Section 4.1.1, OU3 receives discharge from an area immediately to the north of the facility boundary. At the time the samples were collected, the area immediately north of the facility boundary was in the process of being cleared for a golf course and housing development. Furthermore, precipitation events occurred for several days prior to and during the collection of surface water samples and field notes indicate a relatively high silt content in the surface water samples collected from OU3 close to the northern facility boundary. It is likely the ongoing precipitation combined with the ongoing clearing activities resulted in the elevated concentrations of inorganics detected in surface water at OU3 and that previous on-site activities were not the primary source of these chemicals.[7]

4.5 UNCERTAINTIES

As in any ERA, the WRF ERA incorporates a number of uncertainties associated with the estimates of ecological risk. The general approach in this ERA has been to err on the side of conservatism. Accordingly, the risks in this ERA are likely to be overestimated rather than underestimated. However, a complete understanding of the uncertainties associated with the risk estimates is crucial to placing the estimated risks into proper perspective. The main areas of uncertainty associated with the ERA can be grouped under the following categories:

- Environmental Sampling and Analysis and Selection of Chemicals for Analysis;
- Identification of Exposure Pathways/Receptors for Evaluation and Exposure Parameter Estimation;
- Analysis of Toxicological Data; and
- Assessment of Risks.

The major uncertainties in each of these categories are discussed in the following sections.

[7] Only unfiltered samples were taken from surface water and dissolved concentrations could not be determined.

4.5.1 Environmental Sampling and Analysis and Selection of Chemicals of Potential Concern

The major source of uncertainty in the environmental sampling and analysis is associated with the representativeness of the samples taken in surface water. As discussed in Section 4.1.1, the area immediately to the north of WRF, which comprises part of the drainage basin of OU3, was being cleared at the time samples were being collected. The samples were collected during a storm event and runoff from the cleared area most likely contributed to the elevated inorganic chemical concentrations observed in samples taken from the upper reaches of OU3. This "pulse" release of chemicals could overestimate the potential for adverse effects to aquatic life.

There is substantial uncertainty associated with the applicability of the fish tissue data to the evaluation of contamination at OU3. Available fish sampling information suggests fish were collected from the Main Ditch at a location just above the beaver dam, though some fish may have been collected at locations below the dam. As discussed earlier, the fish were collected at a location downstream of where the most downgradient sediment/surface water sample was taken. Although it is likely that fish captured in this area frequently move upstream into the area sampled in OU3, samples collected from this area could potentially over- or underestimate accumulation in the OU3 area, and thus, over- or underestimate potential risks. This potential problem is exacerbated for species, such as sunfish and crappie, which tend to be territorial, and thus, relatively immobile. For chemicals localized to the OU3 area, such as PCB-1260, the collection of fish from the downgradient areas is likely to underestimate risks.

In addition to the location at which fish samples were collected, there is uncertainty associated with the length of time at which the collected fish have been present in the Main Ditch. Several of the fish species collected at WRF are relatively mobile and may move out of the ditch into deeper waters during, for example, periods of environmental stress (e.g., temperature extremes). The dam currently creates a barrier precluding the movement of most fish species. Eels, however, are capable of exiting the water and passing over/around the dam. Further, it is unknown whether the dam can be periodically breached by fish species, such as during storm events. If the dam is breached by either eels or fish then there is the potential for these organisms to have recently entered the ditch from the Occoquan/Belmont Bay introducing uncertainty about the representativeness of the tissue concentrations sampled from the ditch at OU3. The length of time in which a eel/fish has been present in the Main Ditch could result in the under- or overestimate of the potential for accumulation in this water body.

4.5.2 Identification of Exposure Pathways/Receptors for Evaluation and Exposure Parameter Estimation

A number of uncertainties are associated with the identification of potential receptor species and the potential exposure pathways by which these species could be exposed to COPC. Only limited exposure data was available for evaluating many of the potential exposure pathways selected for evaluation in the ERA. In the absence of detailed information, conservative assumptions had to be made in order to estimate exposure of potential ecological receptors to COPC on WRF. For example, it was assumed that heron and mink obtain all of the fish they ingest from OU3 at WRF. Furthermore, it was assumed in the initial analysis that all chemicals detected in fish tissue resulted from accumulation at on-site areas. As discussed in Section 4.4.1, much of the chemicals accumulated in fish tissue are likely to have originated from areas outside of WRF. These assumptions could potentially overestimate the potential for adverse effects to ecological receptors from the ingestion of fish tissue.

There is also uncertainty associated with the potential exposure pathways selected for evaluation in the ERA. For example, the potential for adverse effects to terrestrial wildlife from the dermal absorption or inhalation of chemicals could not be evaluated because of a lack of exposure data. However, based on the COPC detected in the sampled media these potential exposure pathways are unlikely to occur or to result in adverse effects to terrestrial species and the inclusion of these pathways is unlikely to significantly alter the risk estimates.

4.5.3 Analysis of Toxicological Data

There are a number of uncertainties associated with the toxicity values used for the evaluation of potential adverse effects to ecological receptors. There is uncertainty associated with the applicability of

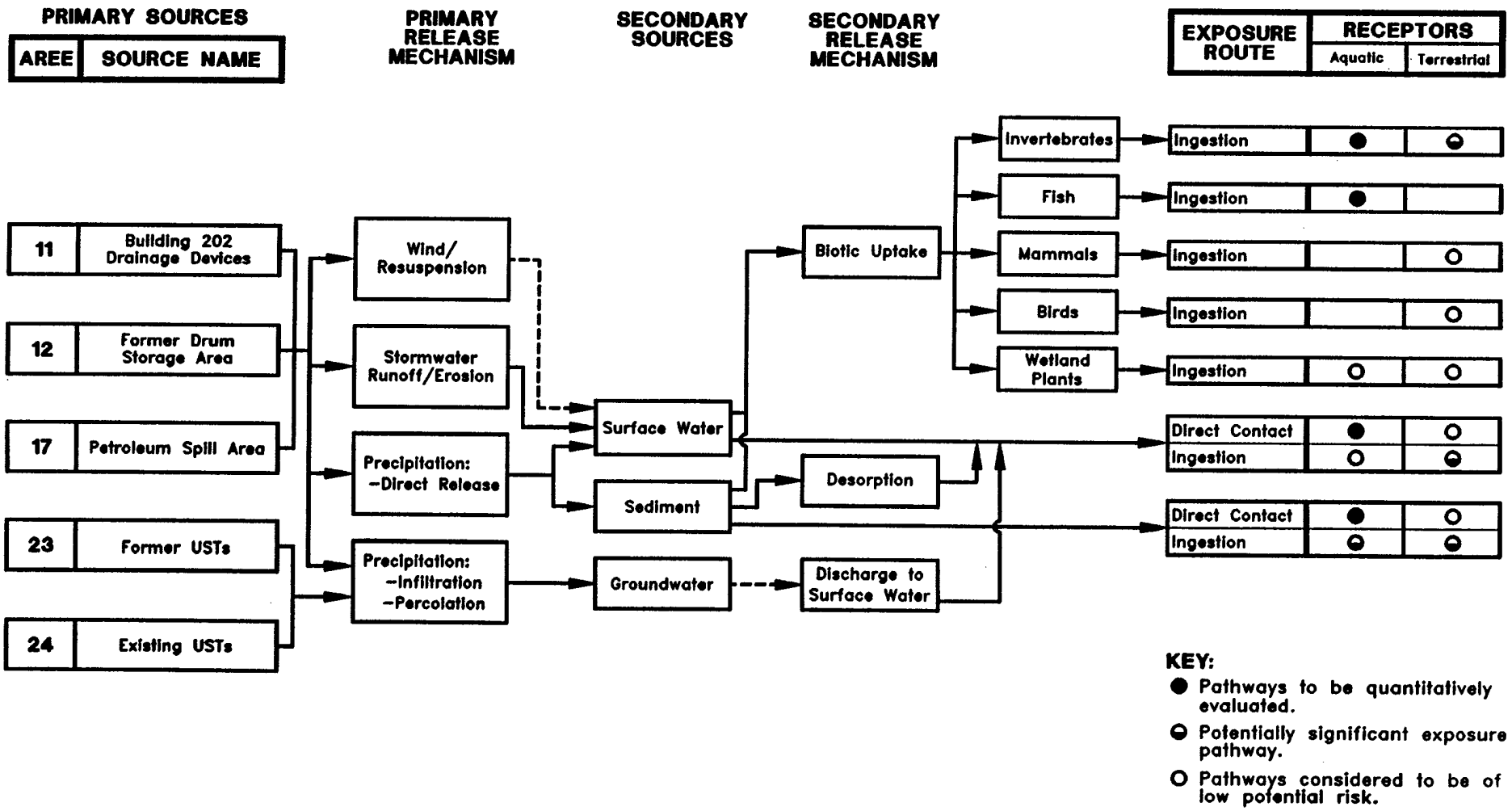
the available toxicity data to the species occurring on WRF. For example, the NOAA ER-L/ER-M values were used to evaluate the potential for adverse effects to benthic organisms in many of the ephemeral surface water bodies on WRF. These toxicity values were derived largely for brackish water habitats and may not be relevant to the aquatic life occurring in the freshwater bodies on WRF.

For the evaluation of potential adverse effects to heron and mink from the ingestion of fish and sediment it was assumed that all of the mercury in fish tissue is present as methylmercury. Because the toxicity of inorganic mercury is always less than the toxicity of methylmercury, and methylmercury is the most toxic form of organic mercury (Eisler, 1987), this assumption is likely to overestimate risks if some fraction of the mercury is present in fish tissue as inorganic mercury.

4.5.4 Assessment of Risks

There are uncertainties associated with the assessment of risks in the ERA. The most apparent uncertainty is the extrapolation of assumptions about the potential for adverse effects from individual organisms to populations or communities. For the higher trophic level terrestrial species, the ERA made conclusions about the potential for adverse effects to individual organisms. Very few models are available to extrapolate the potential for adverse effects from the individual level to the population or community-level. Because of the limited availability of such models, certain assumptions had to be made about the overall potential for adverse effects to ecological receptors. It was generally assumed if there is no potential for direct adverse effects to individual organisms then it is also unlikely for there to be the potential for direct adverse effects to populations or communities. Similarly, it was assumed that if there is the potential for adverse effects to individual organisms there is also the potential for adverse effects to populations or communities. Risks may have been overestimated by this latter assumption.

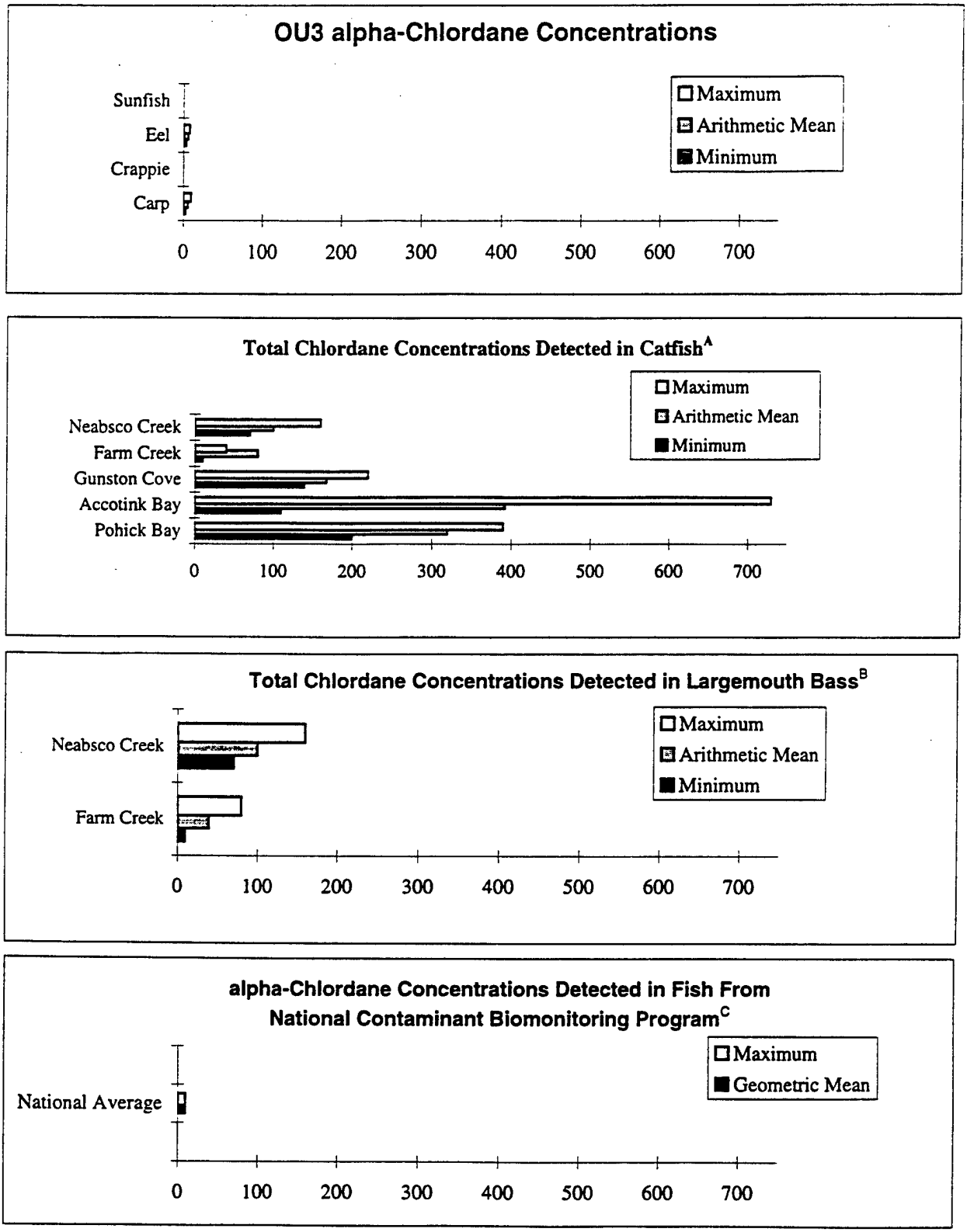
FIGURE 4-1
OU3 SITE CONCEPTUAL MODEL



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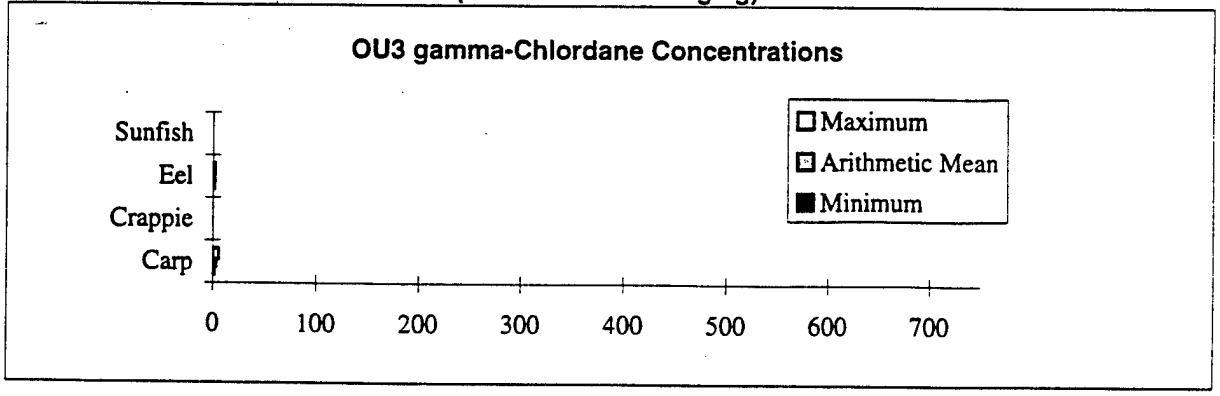
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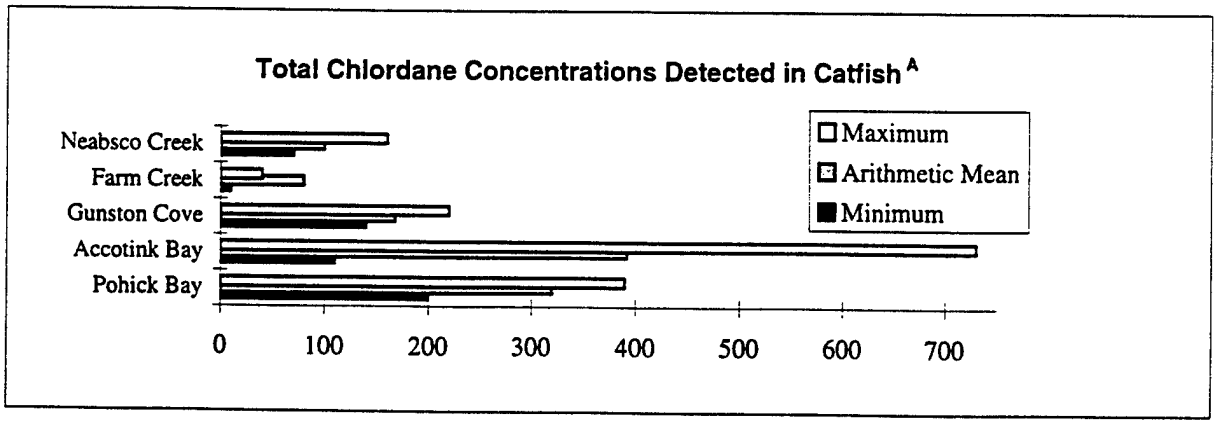
FIGURE 4-2
COMPARISON OF WHOLE BODY ALPHA-CHLORDANE CONCENTRATIONS IN FISH TISSUE FROM OU3 TO REGIONAL/NATIONAL CONCENTRATIONS
(Concentration in ug/kg)

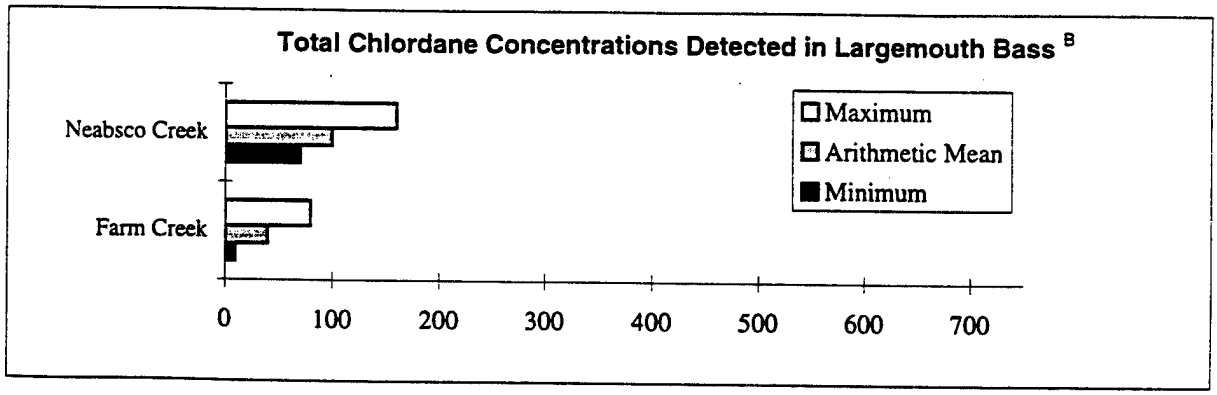


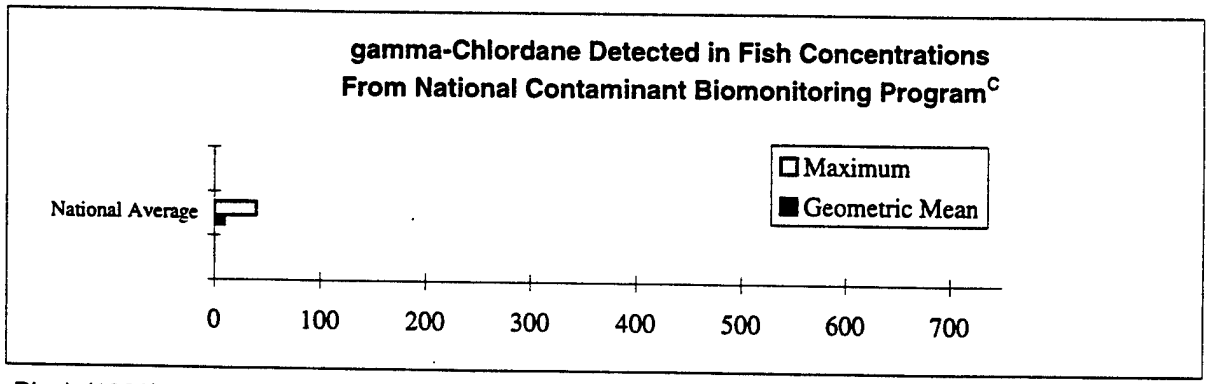
A Block (1990).
B Pinkney et al (1995).
C Schmitt and Brumbaugh (1990).

FIGURE 4-3
COMPARISON OF WHOLE BODY GAMMA-CHLORDANE CONCENTRATIONS IN FISH TISSUE FROM OU3 TO REGIONAL/NATIONAL CONCENTRATIONS
(Concentration in ug/kg)



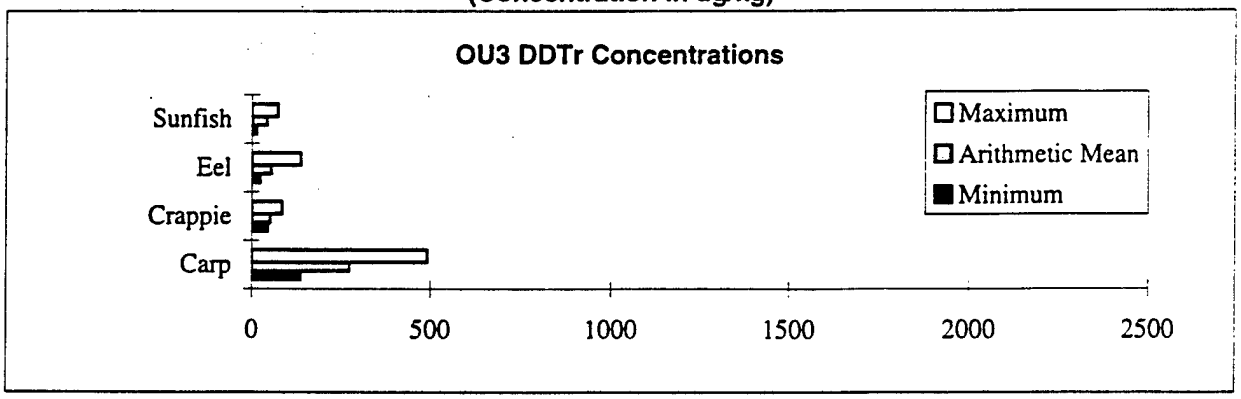


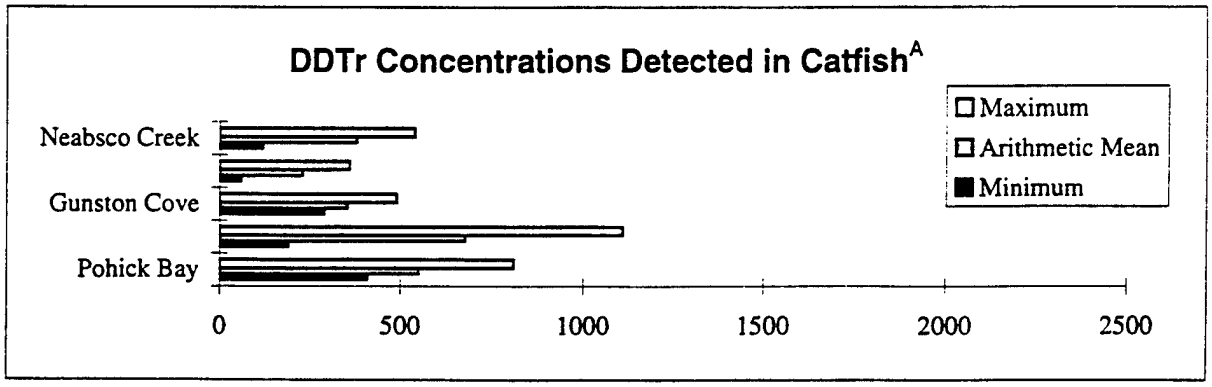


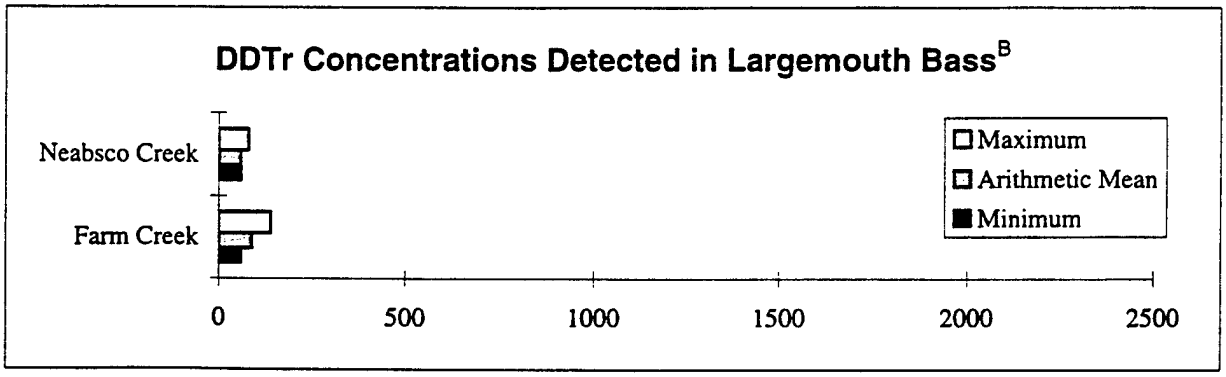


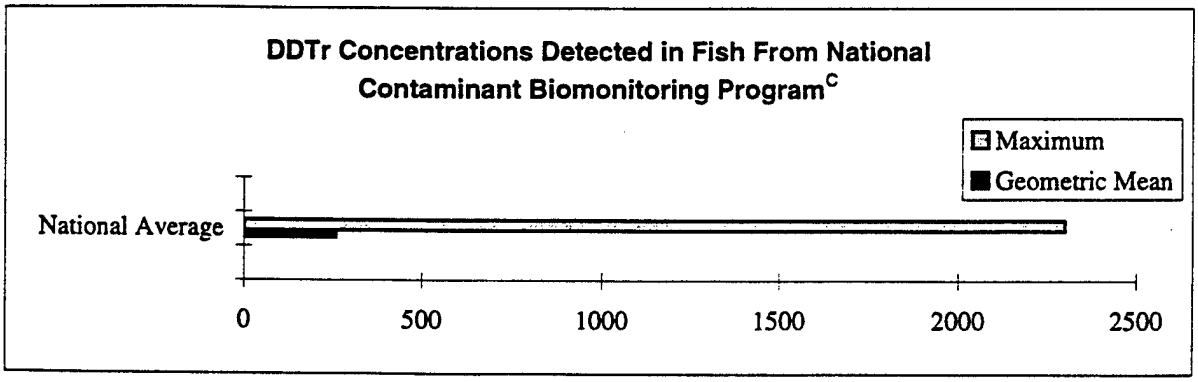
A Block (1990).
B Pinkney et al (1995).
C Schmitt and Brumbaugh (1990).

FIGURE 4-4
COMPARISON OF WHOLE BODY DDTr CONCENTRATIONS IN FISH TISSUE FROM OU3 TO REGIONAL/NATIONAL CONCENTRATIONS
(Concentration in ug/kg)



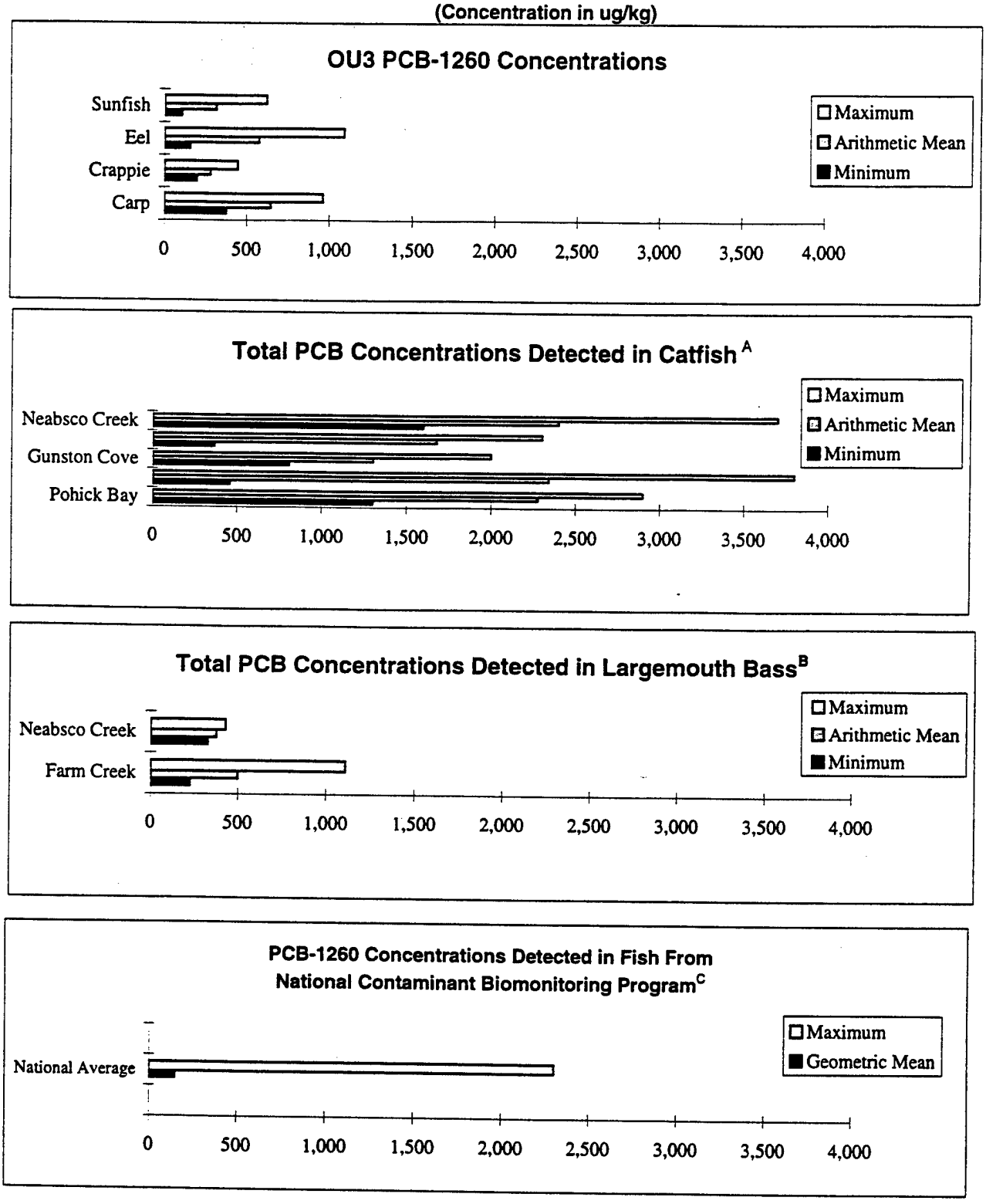






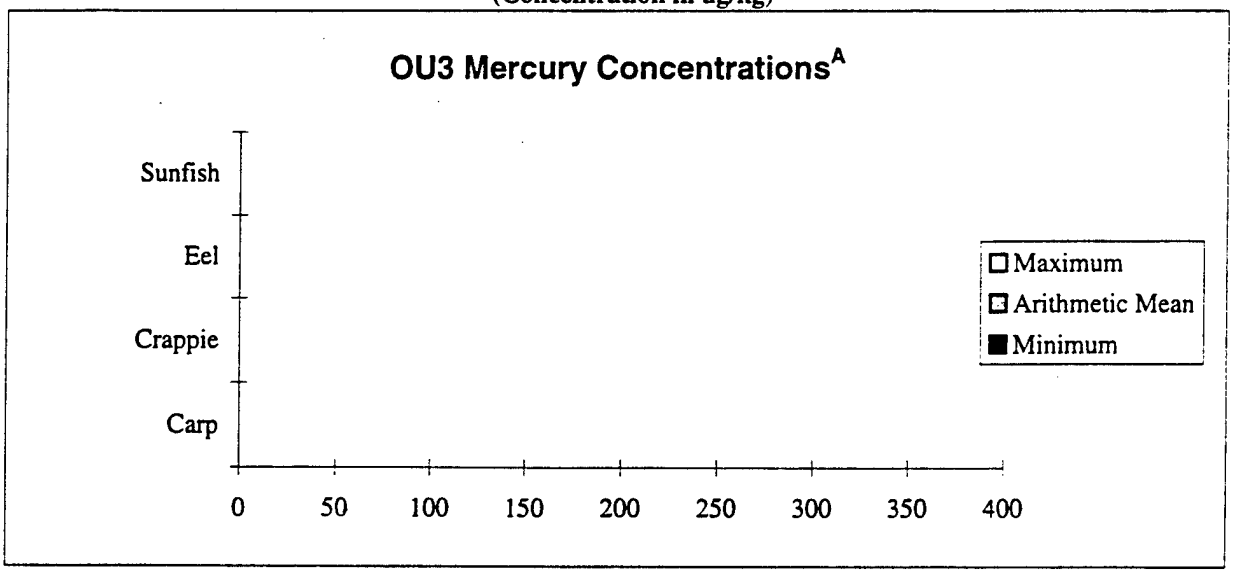
A Block (1990).
B Pinkney et al (1995).
C Schmitt and Brumbaugh (1990).

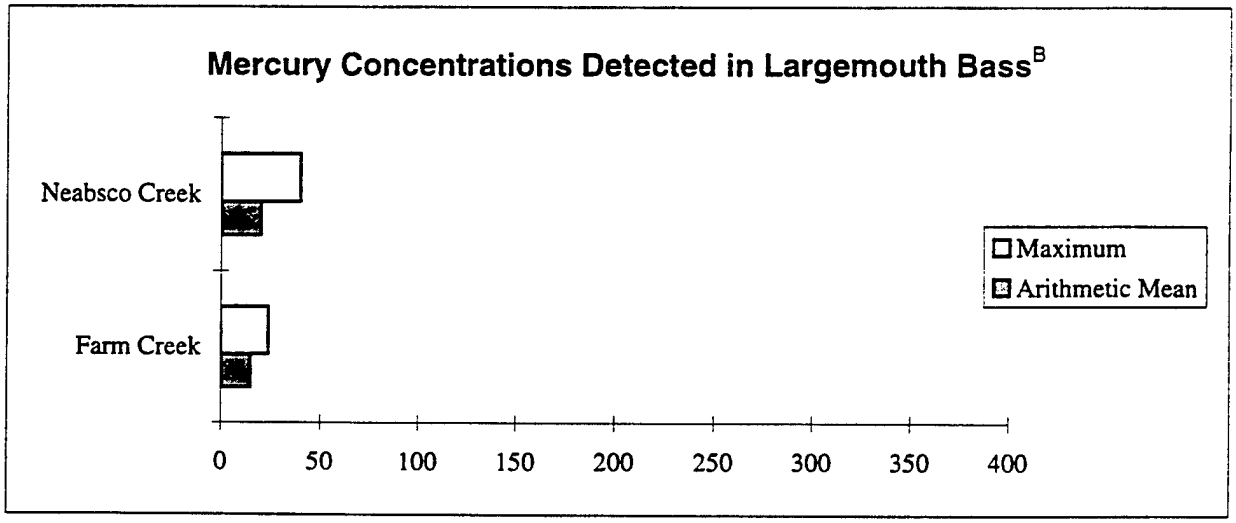
FIGURE 4-5
COMPARISON OF WHOLE BODY PCB-1260 CONCENTRATIONS IN FISH TISSUE FROM OU3 TO REGIONAL/NATIONAL CONCENTRATIONS
(Concentration in ug/kg)

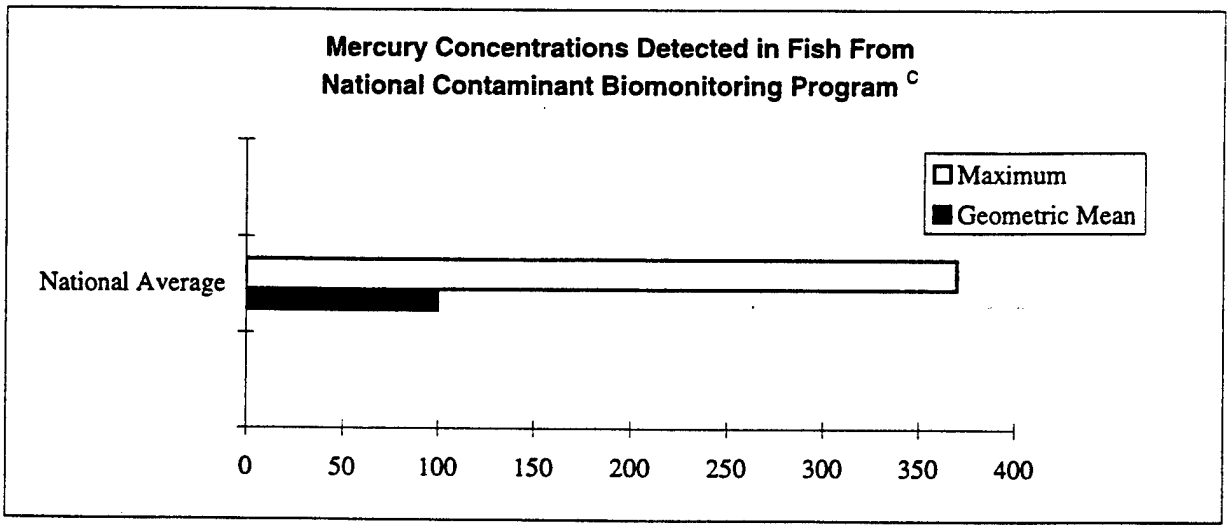


A Block (1990).
B Pinkney et al (1995).
C Schmitt and Brumbaugh (1990).

FIGURE 4-6
COMPARISON OF WHOLE BODY MERCURY CONCENTRATIONS IN FISH TISSUE
FROM OU3 TO REGIONAL/NATIONAL CONCENTRATIONS
(Concentration in ug/kg)







A All detected mercury values are less than 1 mg/kg (see Table 4-3).
B Pinkney et al (1995).
C Schmitt and Brumbaugh (1990).

TABLE 4-1
SUMMARY OF CHEMICALS DETECTED IN OU3 SEDIMENT
(Concentrations in mg/kg)

Chemical	Frequency of Detection (a)	Arithmetic Mean (b)	Range of Detection Limits	Range of Detected Concentrations	Range of Background Concentrations (c)	Site > Background (d)
PAHs						
Acenaphthene	1 / 10	0.191	0.133	1.31	0.668 - 0.919	---
Anthracene	10 / 10	0.0773	NU	0.0230 - 0.190	0.108 - 0.169	---
Benzo(a)anthracene	7 / 8	0.0961	0.013	0.0130 - 0.591	0.0210 - 0.0310	---
Benzo(a)pyrene	9 / 9	0.132	NU	0.0150 - 0.596	0.0290 - 0.0515	---
Benzo(b)fluoranthene	10 / 10	0.0939	NU	0.0090 - 0.347	0.0610 - 0.083	---
Benzo(g,h,i)perylene	6 / 10	0.0451	0.007 - 0.168	0.0210 - 0.0910	0.0460 - 0.0800	---
Benzo(k)fluoranthene	8 / 9	0.0478	0.018	0.0100 - 0.197	0.0170 - 0.0320	---
Chrysene	1 / 1	NC	NU	0.480	ND	---
Dibenzo(a,h)anthracene	3 / 10	0.0104	0.003 - 0.083	0.0120 - 0.0140	0.0130 - 0.022	---
Fluoranthene	9 / 9	0.177	NU	0.0310 - 0.768	0.0550 - 0.094	---
Fluorene	2 / 10	0.0904	0.033	0.313 - 0.459	0.157 - 0.355	---
Indeno(1,2,3-c,d)pyrene	7 / 10	0.0497	0.003 - 0.083	0.0120 - 0.227	0.0640 - 0.112	---
2-Methylnaphthalene	2 / 2	1.51	NU	1.24 - 1.78	ND	---
Naphthalene	4 / 10	0.510	0.133	0.380 - 2.90	0.351	---
Phenanthrene	3 / 5	0.397	0.0330	0.356 - 0.915	ND	---
Pyrene	6 / 7	0.226	0.00700	0.0650 - 0.955	0.0530 - 0.130	---
Pesticides:						
Chlordane (total)	2 / 10	0.0384	0.0200	0.0410 - 0.263	ND	---
alpha-Chlordane	2 / 10	0.00490	0.00300	0.0160 - 0.0210	ND	---
gamma-Chlordane	2 / 10	0.00640	0.00300	0.0220 - 0.0300	ND	---
DDD	2 / 10	0.00520	0.00300	0.0160 - 0.0240	ND	---
PCBs						
PCB-1260	5 / 10	1.14	0.0130	0.0430 - 6.04	ND	---
Inorganics						
Aluminum	10 / 10	13,100	NU	8,980 - 15,900	10,500 - 15,200	No
Barium	10 / 10	140	NU	75.8 - 191	175	**Yes**
Beryllium	10 / 10	1.33	NU	0.715 - 2.44	0.989 - 1.26	No
Calcium	8 / 8	1,890	NU	1,300 - 2,410	4,240 - 6,000	No
Chromium	10 / 10	18.7	NU	13.3 - 23.0	21.6 - 30.1	No
Cobalt	10 / 10	17.1	NU	8.19 - 36.1	14.6 - 20.7	No
Copper	10 / 10	19.4	NU	12.5 - 25.9	29.8 - 41.8	No
Iron	10 / 10	19,400	NU	10,300 - 34,600	26,100 - 34,200	No
Lead	10 / 10	46.1	NU	20.9 - 84.5	22.775 - 42.2	**Yes**
Magnesium	9 / 9	1,480	NU	1,010 - 1,830	2,470 - 3,470	No
Manganese	8 / 8	381	NU	216 - 564	911.5 - 1,690	No
Nickel	10 / 10	13.0	NU	7.72 - 19.1	19.3 - 30.0	No
Potassium	2 / 2	1,020	NU	991 - 1,040	1,450 - 2,120	No

TABLE 4-1
SUMMARY OF CHEMICALS DETECTED IN OU3 SEDIMENT
(Concentrations in mg/kg)

Chemical	Frequency of Detection (a)	Arithmetic Mean (b)	Range of Detection Limits	Range of Detected Concentrations	Range of Background Concentrations (c)	Site > Background (d)
Sodium	10 / 10	870	NU	565 - 1,240	932 - 1,710	No
Vanadium	10 / 10	47.3	NU	28.9 - 68.8	35.5 - 52.5	No
Zinc	10 / 10	128	NU	57.6 - 257	114 - 157	No

(a) The number of samples in which the chemical was detected divided by the total number of samples analyzed.
(b) Consists of data from sample locations RISD26 through 35.
(c) Consists of data from sample locations RISDBK1 through 5.
(d) Statistical comparisons to background were not performed on organics.
ND = Not Detected.
NU = Not used. The chemical was detected in all samples, thus detection limits were not used to calculate mean concentrations.

TABLE 4-2
SUMMARY OF CHEMICALS DETECTED IN OU3 SURFACE WATER
(Concentrations in ug/L)

Chemical	Frequency of Detection (a)	Arithmetic Mean (b)	Range of Detection Limits	Range of Detected Concentrations	Range of Background Concentrations (c)	Site > Background? (d)
PAHs						
Fluoranthene	2 / 10	0.0129	0.0200	0.0230 - 0.0260	ND	---
Inorganics:						
Aluminum	10 / 10	13,100	NU	10,500 - 16,100	1,230 - 1,930	**Yes**
Barium	10 / 10	71.8	NU	58.2 - 109	37.7 - 41.8	**Yes**
Cadmium	7 / 10	0.115	0.100	0.100 - 0.300	ND	**Yes**
Calcium	10 / 10	6,640	NU	4,840 - 8,600	18,800 - 22,200	No
Chromium	8 / 10	10.6	10.0	10.3 - 14.8	10.8	**Yes**
Copper	10 / 10	7.07	NU	5.10 - 8.20	ND	**Yes**
Iron	10 / 10	11,400	NU	7,900 - 17,300	1,905 - 2,510	No
Lead	9 / 10	7.52	1.0	4.80 - 13.0	1.30 - 1.90	**Yes**
Magnesium	10 / 10	2,660	NU	2,460 - 2,900	5,970 - 7,500	No
Manganese	10 / 10	369	NU	171 - 624	176 - 303	No
Potassium	10 / 10	3,800	NU	3,520 - 4,280	2,870 - 3,670	**Yes**
Sodium	10 / 10	2,340	NU	2,110 - 2,650	12,500 - 16,500	No
Thallium	8 / 10	0.14	0.100	0.100 - 0.200	ND	**Yes**
Vanadium	10 / 10	25.1	NU	17.5 - 30.1	ND	**Yes**
Zinc	10 / 10	47.1	NU	30.7 - 78.0	ND	**Yes**

(a) The number of samples in which the chemical was detected divided by the total number of samples analyzed.
(b) Consists of data from sample locations RISW26 through 35.
(c) Consists of data from sample locations RISWBK1 through 5.
(d) Statistical comparisons to background were not performed on organics.
ND = Not Detected.
NU = Not used. The chemical was detected in all samples, thus detection limits were not used to calculate mean concentrations.

TABLE 4-3
SUMMARY OF CHEMICALS DETECTED IN OU3 WHOLE BODY FISH TISSUE

Chemical	Frequency of Detection (a)	Arithmetic Mean (b)	Range of Detection Limits	Range of Detected Concentrations
WHOLE BODY CONCENTRATIONS				
(ug/kg organics and ug/g inorganics - wet weight)				
Carp				
Pesticides:				
alpha-Chlordane	3 / 3	6.14	NU	3.26 - 9.97
gamma-Chlordane	3 / 3	3.66	NU	2.19 - 5.85
DDD	3 / 3	171	NU	75.9 - 325
DDE	3 / 3	103	NU	61.2 - 167
PCBs:				
PCB-1260	3 / 3	648	NU	379 - 962
Crappie				
Pesticides:				
DDE	5 / 5	53	NU	33.6 - 84.3
PCBs:				
PCB-1260	5 / 5	284	NU	201 - 447
Inorganics:				
Mercury	5 / 5	0.151	NU	0.100 - 0.207
Eel				
Pesticides:				
alpha-Chlordane	4 / 4	6.12	NU	3.39 - 8.25
gamma-Chlordane	4 / 4	1.92	NU	1.35 - 2.31
DDD	1 / 4	21.0	1.0	82.3
DDE	4 / 4	34.5	NU	23.7 - 54.6
PCBs:				
PCB-1260	4 / 4	576	NU	158 - 1,090
Inorganics:				
Mercury	2 / 4	0.0408	0.0460 - 0.0480	0.0540 - 0.0620
Sunfish				
Pesticides:				
DDE	5 / 5	42.8	NU	14.4 - 73.5
Heptachlor	1 / 5	0.684	1.0	1.42
PCBs:				
PCB-1260	5 / 5	319	NU	107 - 620
Inorganics:				
Mercury	1 / 5	0.0321	0.0460 - 0.0480	0.0670

TABLE 4-3
SUMMARY OF CHEMICALS DETECTED IN OU3 WHOLE BODY FISH TISSUE

Chemical	Frequency of Detection (a)	Arithmetic Mean (b)	Range of Detection Limits	Range of Detected Concentrations
All Fish Combined				
Pesticides:				
alpha-Chlordane	7 / 17	2.82	1.0	3.26 - 9.97
gamma-Chlordane	7 / 17	1.39	1.0	1.35 - 5.85
DDD	4 / 17	35.5	1.0	75.9 - 325
DDE	17 / 17	54.5	NU	14.4 - 167
Heptachlor	1 / 17	0.554	1.0	1.42
PCBs:				
PCB-1260	17 / 17	427	NU	107 - 1,090
Inorganics:				
Mercury	8 / 17	0.0677	0.0460 - 0.0490	0.0540 - 0.207
LIPID ADJUSTED WHOLE BODY CONCENTRATIONS				
(ug/kg-lipid organics and ug/g-lipid inorganics - wet weight)				
Carp				
Pesticides:				
alpha-Chlordane	3 / 3	203	NU	122 - 302
gamma-Chlordane	3 / 3	122	NU	81.7 - 177
DDD	3 / 3	5,580	NU	2,832 - 9,848
DDE	3 / 3	3,430	NU	2,284 - 5,061
PCBs:				
PCB-1260	3 / 3	21,600	NU	14,142 - 29,152
Crappie				
Pesticides:				
DDE	5 / 5	2,100	NU	1,672 - 2,678
PCBs:				
PCB-1260	5 / 5	11,300	NU	8,949 - 14,194
Eel				
Pesticides:				
alpha-Chlordane	4 / 4	109	NU	63.0 - 153
gamma-Chlordane	4 / 4	34.3	NU	25.1 - 44.0
DDD	1 / 4	448	13.5 - 19.0	1,766
DDE	4 / 4	652	NU	340 - 1,172

TABLE 4-3
SUMMARY OF CHEMICALS DETECTED IN OU3 WHOLE BODY FISH TISSUE

Chemical	Frequency of Detection (a)	Arithmetic Mean (b)	Range of Detection Limits	Range of Detected Concentrations
PCBs:				
PCB-1260	4 / 4	9,920	NU	2,937 - 16,803
Sunfish				
Pesticides:				
DDE	5 / 5	2,510	NU	460 - 4,375
Heptachlor	1 / 5	33.7	55.9 - 67.1	45.4
PCBs:				
PCB-1260	5 / 5	18,500	NU	3,419 - 34,637
All Fish Combined				
Pesticides:				
alpha-Chlordane	7 / 17	76.0	23.0 - 67.1	63.0 - 302
gamma-Chlordane	7 / 17	44.0	23.0 - 67.1	25.1 - 177
DDD	4 / 17	1,100	13.5 - 67.1	1,766 - 9,848
DDE	17 / 17	2,110	NU	340 - 5,061
Heptachlor	1 / 17	21.4	13.5 - 67.1	45.4
PCBs:				
PCB-1260	17 / 17	14,900	NU	2,937 - 34,637

(a) The number of samples in which the chemical was detected divided by the total number of samples analyzed.
(b) Calculated by averaging the detected concentration(s) with one-half the detection limit of non-detected sample(s).
NU = Not used. The chemical was detected in all samples, thus detection limits were not used to calculate mean concentrations

Table 4–4. Potential Exposure Pathways for Ecological Receptors in OU3

Potential Receptors	Exposure Route	Pathway(s) Selected for Evaluation?	Comments
SURFACE WATER			
Terrestrial wildlife	Ingestion	No	Pathway potentially complete; however, not evaluated quantitatively because detected chemical concentrations are unlikely to adversely affect terrestrial wildlife.
	Direct contact (dermal absorption)	No	Not evaluated because applicable exposure and toxicity data could not be found in the scientific literature; however, pathway is not likely to result in significant risks because exposure is likely to be limited.
Aquatic life	Ingestion, respiration, and direct contact (dermal absorption)	Yes	Pathway potentially complete; selected for quantitative evaluation.
Wetland/aquatic plants	Direct contact (root and foliar uptake)	No	Pathway not evaluated because applicable exposure and toxicity data could not be found in the scientific literature.
SEDIMENT			
Terrestrial wildlife (e.g., mammals, birds)	Ingestion	Yes	Pathway potentially complete; selected for quantitative and/or qualitative evaluation.
	Direct contact (dermal absorption)	No	Not selected for evaluation because applicable exposure and toxicity data could not be found in the scientific literature; however, pathway is not likely to result in significant risks because exposure is likely to be limited.
Benthic-dwelling aquatic life	Ingestion, respiration, and direct contact (dermal absorption)	Yes	Pathway potentially complete; selected for quantitative evaluation.

Table 4–5. Potential Exposure Routes for Terrestrial Mammals from the Ingestion of Foods in OU3

Feeding Guild	Representative Food Types	Representative Species[a,b]	Exposure Route Selected for Evaluation?
Herbivores/Granivores	Aquatic vegetation, seeds, fruit	Meadow vole Gray squirrel Eastern cottontail Whitetail deer	No. Not evaluated because applicable exposure and toxicity data could not be found in the scientific literature. However, vegetative material associated with OU3 is not expected to significantly accumulate the chemicals detected in surface water or sediment, and this pathway was not selected for further evaluation.
Piscivores	Fish	River otter Mink	Yes. Chemicals having the potential to accumulate in fish were detected in sediment and in fish tissue, therefore, this potential exposure pathway was selected for evaluation.
Small Mammal/ Avian Predators	Small mammals (e.g., rabbits, mice), small birds	Long-tailed weasel	No. Chemicals having the potential to accumulate in small mammals were detected in sediment and associated food items (e.g., fish, aquatic plants). However, weasels are likely to forage on a variety of different small mammals and most small mammals likely to be consumed by weasels are expected to have very little exposure to chemicals in OU3. Accordingly, adverse effects are considered unlikely, and this potential exposure pathway was not selected for further evaluation.
Omnivores	Aquatic invertebrates, fish, small mammals, birds, carrion, fruits, seeds	Virginia opossum Raccoon Red fox	Yes. Chemicals having potential to accumulate in aquatic invertebrates were detected in sediment. Raccoon consume clams, which were observed at WRF, and this pathway is potentially complete. However, this potential exposure pathway will be evaluated as part of the sitewide WRF ERA. Other potential exposure pathways for omnivores were not selected for evaluation because other receptors for which the pathway represents a larger proportion of their diet were selected for evaluation.

[a]This list provides examples of species known or likely to occur at WRF and is not intended to be comprehensive.
[b]The listed species were classified according to predominant food type. It should be noted, however, that some of the species listed may consume a variety of different food types depending upon their availability.

Table 4–6. Potential Exposure Routes for Avian Species from the Ingestion of Foods in OU3

Feeding Guild	Representative Food Types	Representative Species[a,b]	Exposure Route Selected for Evaluation?
Dabblers	Aquatic and terrestrial plants, aquatic invertebrates	Black duck Greater Scoup Mallard Wood duck	Yes. Chemicals having the potential to accumulate in aquatic invertebrates were detected in sediment. However, this potential exposure pathway will be evaluated as part of the sitewide WRF ERA. Vegetative material associated with OU3 is not expected to significantly accumulate the chemicals detected in surface water or sediment.
Piscivores	Fish	Bald eagle[c] Belted kingfisher Great black-backed gull Great blue heron[c] Black-crowned night heron[c] Little blue heron[c] Greenback heron[c] Mergansers Osprey	Yes. Chemicals having the potential to accumulate in fish were detected in sediment and fish tissue, therefore, this potential exposure pathway was selected for evaluation.
Small Mammal/Bird Predators	Small mammals (e.g., rabbits, shrews, mice), small birds	Bald eagle[c] Red-tailed hawk Red-shouldered hawk Barn owl	No. Chemicals having the potential to accumulate in small mammals and birds were detected in sediment and associated food items (e.g., fish, aquatic plant). However, most small mammals and birds are expected to have very little exposure to chemicals in the Main Ditch. Accordingly, adverse effects are considered unlikely, and this potential exposure pathway was not selected for further evaluation.

[a]This list provides examples of species known or likely to occur at WRF and is not intended to be comprehensive.
[b]The listed avian species were classified according to predominant food type. It should be noted, however, that some of the avian species listed may consume a variety of different foods depending upon their availability. Species that were classified in more than one of the above categories have been noted.
[c]Bald eagles and heron consume fish, small mammals/rodents, and birds and could be listed in more than one of the above categories.

Table 4–7. Assessment Endpoints for Ecological Risk Assessment of OU3

Receptor of Concern	Exposure Pathway Evaluated	Assessment Endpoint	Testable Hypothesis	Measurement Endpoint	Data Available
Piscivorous birds (heron)	Ingestion of chemicals accumulated in fish and from sediment	Decline in heron populations	Ha: The ingestion of bioaccumulative chemicals from fish and sediment exceeds a level known to be toxic to heron	Compare dose of bioaccumulative chemicals from ingestion of fish and sediment, estimated by both modeling and tissue residue analyses, to toxicity benchmarks in literature	Site-specific sediment chemical data from potentially impacted locations and reference locations Site-specific fish tissue residue data from potentially impacted locations
Small piscivorous mammal (mink)	Ingestion of chemicals accumulated in fish and from sediment	Decline in mink populations	Ha: The ingestion of bioaccumulative chemicals from fish and sediment exceeds a level known to be toxic to mink populations	Compare dose of bioaccumulative chemicals from ingestion of fish and sediment, estimated by both modeling and tissue residue analyses, to toxicity benchmarks in literature	Site-specific sediment chemical data from potentially impacted locations and reference locations Site-specific fish tissue residue data from potentially impacted locations and reference locations
Aquatic life	Ingestion, respiration, and dermal absorption	Decline in abundance and diversity of aquatic community	Ha: The concentration of chemicals of potential concern within surface water exceeds a level known to be toxic to aquatic life	Compare chemical concentrations in surface water at potentially impacted locations to toxicity benchmarks in literature	Site-specific surface water chemical data from potentially impacted locations and reference locations
Benthic-dwelling aquatic life	Ingestion, respiration, and dermal absorption	Decline in abundance and diversity of benthic macroinvertebrate community	Ha: The concentration of chemicals of potential concern within sediment exceeds a level known to be toxic to benthic macroinvertebrates	Compare chemical concentrations in sediment at potentially impacted locations to toxicity benchmarks in literature	Site-specific sediment chemical data from potentially impacted locations and reference locations

Table 4-8

COMPARISON OF ARITHMETIC MEAN DIETARY CONCENTRATIONS TO DIETARY TRVs FOR CHEMICALS OF POTENTIAL CONCERN DETECTED IN OU3

Chemical	Arithmetic Mean Dietary Concentrations (mg/Kg*day)		No Observed Adverse Effect Levels [A] (mg/Kg*day)		Environmental Effects Quotient (EEQ)	
	Mink	Great Blue Heron	Mink	Great Blue Heron	Mink	Great Blue Heron
Chlordane (total)	0.0014	0.0013	1.44	0.648	<0.1	<0.1
DDT & Metabolites	0.012	0.016	0.566	0.00032	<0.1	**49.9**
Heptachlor	0.00007	ND	0.566	---	<0.1	---
PCB-1260	0.081	0.092	0.137 [B]	0.135 [B]	0.59	0.7
Mercury	0.0091	0.029	0.015 [C]	0.005 [D]	0.606	**5.8**

ND = Not Detected

A NOAELs from Opresko et al (1994).

B Value for PCB-1254 used.

C Value for methyl mercury chloride used.

D Value for methyl mercury dicyanamide used.

TABLE 4-9

COMPARISON OF MAXIMUM CONCENTRATIONS TO SEDIMENT TRVs FOR CHEMICALS OF POTENTIAL CONCERN DETECTED IN OU3 SEDIMENTS

Units = mg/Kg

Chemical	Maximum Sediment Concentration	ER-L[A]	ER-M[A]	Other Guidelines	Environmental Effects Quotient (EEQ)		
					Ratio of Maximum Sediment Concentrations to ER-L	Ratio of Maximum Sediment Concentrations to ER-M	Ratio of Maximum Sediment Concentrations to Other Guidelines
PAHs:							
Acenaphthene	1.31	0.016	0.5	---	81.9	2.6	---
Anthracene	0.190	0.085	1.1	---	2.2	0.2	---
Benzo(a)anthracene	0.591	0.261	1.6	---	2.3	0.4	---
Benzo(a)pyrene	0.596	0.43	1.6	---	1.4	0.4	---
Benzo(b)fluoranthene	0.347	---	---	0.24 [B,C]	---	---	1.4
Benzo(g,h,i)perylene	0.0910	---	---	0.17 [B]	---	---	0.5
Benzo(k)fluoranthene	0.197	---	---	0.24 [B]	---	---	0.8
Chrysene	0.480	0.384	2.8	---	1.3	0.2	---
Dibenzo(a,h)anthracene	0.0140	0.0634	0.26	---	0.2	0.1	---
Fluoranthene	0.768	0.6	5.1	---	1.3	0.2	---
Fluorene	0.459	0.019	0.54	---	24.2	0.9	---
Indeno(1,2,3-c,d)pyrene	0.227	---	---	0.2 [B]	---	---	1.1
2-Methylnaphthalene	1.78	0.07	0.67	---	25.4	2.7	---
Naphthalene	2.90	0.16	2.1	---	18.1	1.4	---
Phenanthrene	0.915	0.24	1.5	---	3.8	0.6	---
Pyrene	0.955	0.665	2.6	---	1.4	0.4	---
Pesticides:							
Chlordane (total)	0.263	0.0005 [D]	0.006 [D]	---	526.0	43.8	---
alpha-Chlordane	0.0210	0.0005 [D]	0.006 [D]	---	42.0	3.5	---
gamma-Chlordane	0.0300	0.0005 [D]	0.006 [D]	---	60.0	5.0	---
DDD	0.0240	0.002 [D]	0.02 [D]	---	12.0	1.2	---
PCBs:							
PCB-1260	6.04	---	---	0.005 [B]	---	---	1,208
Inorganics:							
Barium	191	---	---	---	---	---	---
Lead	84.5	46.7	218	---	1.8	0.4	---

ER-L = Effects Range - Low. Concentration of chemical in sediment at which there is the potential for adverse affects to sensitive benthic organism life stages and/or species.
ER-M = Effects Range - Median. Concentration of chemical in sediment at which there is the potential for adverse effects to most benthic organisms.
--- = Value not available.

A All ER-L's and ER-M's from Long et al. (1995) unless otherwise noted.
B Lowest Effect Level (LEL) from OMEE (1993).
C LEL for benzo(k)fluoranthene used.
D ER-L and ER-M from NOAA (1991).

TABLE 4-10

COMPARISON OF CONCENTRATIONS TO SURFACE WATER TRVs FOR
CHEMICALS OF POTENTIAL CONCERN DETECTED IN OU3 SURFACE WATER

Units = ug/L

Chemical	Arithmetic Mean Surface Water Concentration	Surface Water TRVs		Environmental Effects Quotient (EEQ) Ratio of Arithmetic Mean Surface Water Concentrations to TRVs	
		Chronic	Acute	Chronic	Acute
PAH:					
Fluoranthene	0.0129	6.16 [A]	3,980 [A]	<0.1	<0.1
Inorganics:					
Aluminum	13,100	87 [A]	750 [A]	**150.6**	**17.5**
Barium	71.8	3.8 [B]	69.1 [B]	**18.9**	1.0
Cadmium	0.115	0.66 [A]	1.8 [A]	<0.1	<0.1
Chromium	10.6	11 [B,C]	16 [B,C]	1.0	0.7
Copper	7.07	6.5 [A]	9.2 [A]	**1.1**	0.8
Lead	7.52	1.3 [B]	33.8 [B]	**5.8**	0.2
Thallium	0.14	40 [A]	1,400 [A]	<0.1	<0.1
Vanadium	25.1	19.1 [B]	284 [B]	**1.3**	0.1
Zinc	47.1	58.9 [A]	78.5 [A]	0.8	0.6

A US EPA Ambient Water Quality Criteria (1992b,1995). Hardness value of 50.0 mg/L was used in hardness-dependent equations because the detected value of 31.2 mg/L was too low to be used in the regression equation.

B Value from Suter and Mabrey (1994)

C Value for chromium IV.

5.0 APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

5.1 INTRODUCTION

Potential ARARs will be used to support decisions on the ultimate selection of remedial actions necessary at WRF OU3. Although WRF is not a National Priorities List (NPL) site, the NCP remedial selection process is being followed as a model. For a NPL site, the identification of ARARs would be achieved by examining the body of federal, state, and local environmental laws, regulations, and standards. The identification of ARARs is an iterative process and may be more detailed in the future. The final determination of ARARs will be made by the Army after public review, as a part of the final selection of the remedial action and will be documented in the Decision Document for OU3. Listed below are the three elements of ARARs and the three types of ARARs (USEPA, 1988).

5.1.1 Three Elements of Applicable or Relevant and Appropriate Requirements

1. **Applicable Requirements** are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law, that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site.

2. **Relevant and Appropriate Requirements** are those same standards mentioned above that, while not "applicable" at the site, address problems or situations sufficiently similar to those encountered at the site that their use is well-suited to the particular site. The determination of relevant and appropriate is a two-step process: 1) determining if a requirement is relevant and 2) determining if a requirement is appropriate. A requirement that is judged to be both relevant and appropriate must be complied with to the same degree as if it were applicable.

3. **To-Be-Considered Requirements** are other nonpromulgated advisories or guidance issued by state or federal governments that are not legally binding and do not have the status of ARARs. TBC requirements are evaluated along with ARARs in determining site requirements. They complement but do not override ARARs. They may be used in guiding decisions for cleanup levels or methodologies for which mandatory standards are not available.

5.1.2 Three Types of Applicable or Relevant and Appropriate Requirements

1. **Chemical-specific:** are health- or risk-based numerical values limiting the amount of a contaminant that may be released to, or allowed to remain in, the environment during and upon successful completion a remedial action. These include Safe Drinking Water Act Maximum Contaminant Levels (MCLs).

2. **Location-specific:** are those requirements that may restrict or prohibit remedial action because of the site's location, such as a floodplain, wetland, or historical area.

3. **Action-specific:** are remedial technology- or activity-based requirements that may include, for example, removal actions, National Pollutant Discharge Elimination System (NPDES) permit effluent standards, or incinerator destruction standards.

5.2 WOODBRIDGE RESEARCH FACILITY OPERABLE UNIT THREE APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

The federasl ARARs presented in Section 5.1 were analyzed together with state and local ARARs to determine which need to be attained at WRF OU3. Preliminary determinations are discussed below and are summarized in Table 5-1.

5.2.1 Chemical-Specific Applicable or Relevant and Appropriate Requirements

5.2.1.1 Groundwater Applicable or Relevant and Appropriate Requirements

The chemical-specific groundwater ARARs for this project are the MCLs. The MCLs are used as water quality standards for the protection human health from the consumption of groundwater that is/or may be used as a drinking water source.

5.2.1.2 Sediment Applicable or Relevant and Appropriate Requirements

Elevated levels of organic compounds, particularly PCBs, have been detected in the sediment at OU3. There is a limited potential for adverse affects to occur from exposure to these compounds for ecological receptors. The sediment TBC guidance is the USEPA Region III, BTAG recommendation of a cleanup standard for PCBs in sediment of 1.0 ppm to be protective of ecological receptors.

5.2.1.3 Soil Applicable or Relevant and Appropriate Requirements

Elevated levels of PCBs have been detected in subsurface soil at OU3. Toxic Substances Control Act (TSCA) and the Virginia Hazardous Waste Management Regulations (VHWMR) mandate the removal and disposal of PCB-contaminated soils above 50 ppm PCBs. If PCB-contaminated soils are detected above this limit then these regulations would apply to OU3. Therefore, this regulation is retained for consideration as an ARAR for the site.

5.2.1.4 Surface Water Applicable or Relevant and Appropriate Requirements

Remedial alternatives (i.e., removal, chemical oxidation, bioslurry, and/or stream relocation, as discussed in Sections 6.0, 7.0, and 8.0, may impact surface water quality by disturbing the sediment. Contaminants in the sediment could be released into the surface water when the sediment is disturbed during remedial activities; therefore, chemical-specific ARARs related to surface water quality are listed in Table 5-1.

5.2.2 Location-Specific Applicable or Relevant and Appropriate Requirements

Location-specific ARARs set restrictions on remedial action activities depending on the characteristics of a site or its immediate environs. The location-specific ARARs that may be considered depending on the remedial action taken at OU3 are listed in Table 5-1.

5.2.2.1 Cultural and Historical Considerations

Preliminary investigation has indicated that no cultural or historic points are in the area potentially affected by a remedial action at OU3. If a remedial action is selected, consultation with the State Historic Preservation Office will occur (in compliance with 36 CFR Part 800).

5.2.2.2 Rare, Threatened or Endangered Species

The existence of only one endangered species (bald eagle [*Haliaeetus leucocephalus*]), has been confirmed at WRF. No known bald eagle nests occur at WRF, though a communal bald eagle roost is present on Mason Neck, located to the east of the facility. Eagles are known to frequently travel between Mason Neck and WRF. If a remedial action is selected and implemented, any work performed which may impact the activities of the bald eagle will be coordinated with the USFWS.

If a remedial action alternative which requires site modifications is selected, regulations promulgated under the Endangered Species Act of 1973, Bald and Golden Eagle Protection Act of 1940, the Migratory Bird Treaty Act of 1918, and the regulations for the protection of threatened and endangered species with the Virginia Code, Section 29.563, may be ARARs.

5.2.3 Action-Specific Applicable or Relevant and Appropriate Requirements

Action-specific ARARs for this project are limited to alternatives involving engineered actions on site, and any activities conducted off site. This would include such things as proper management and transportation of solid wastes, and proper health and safety assurances during site construction. Since PCBs have been detected in sediment and may be removed and disposed off site, the Virginia Solid Waste Management Regulations would be ARARs.

TABLE 5-1
IDENTIFICATION OF CHEMICAL-SPECIFIC ARARs FOR GROUNDWATER AND SURFACE WATER FOR OU3

Authority	Requirement	Status	Requirement Synopsis
Federal Regulatory Requirement	Safe Drinking Water Act (SDWA)- Maximum Contaminant Levels (MCLs), (40 CFR 141.11 - 141.16)	Relevant and Appropriate	MCLs regulate the concentration of common organic and inorganic contaminants in public drinking water supplies based on health effects and technical capabilities. MCLs may also be considered relevant and appropriate for groundwater aquifers potentially used for drinking water. The MCLs have been used as a screening guidance to evaluate the need for institutional controls at WRF due to risks associated with groundwater. Since the MCLs have been exceeded for some compounds at the WRF, institutional controls may be established to assure that the groundwater will not be developed as a water supply source at the site.
	Clean Water Act (33 U.S.C. 1314), U.S. EPA Office of Water, Federal Ambient Water Quality Criteria (AWQC)	Relevant and Appropriate	Federal AWQCs are surface water criteria developed for protection of human health, freshwater and marine aquatic life. These standards also apply to any stormwater or applied water that flows from the regulated unit to the land surface.
State Regulatory Requirement	Virginia Water Quality Standards (VR 680-21-00/9 VAC 25-260-10 et seq.)	Applicable	The State of Virginia regulates inorganic and organic contaminants in surface water for protection of aquatic life and human health. These standards also apply to a small mixing zone in which wastewater mixes with the receiving water body. This may be appropriate if it is determined that contaminated groundwater is discharging to a surface water body at some point during the long-term monitoring program.
	Virginia Pollutant Discharge Elimination System (VPDES), (VR 680-14-01/9 VAC 25-30-10 et seq.)	Applicable	Any treated groundwater, decontamination water or other wastewater to be discharged to surface waters must meet effluent discharge limits established by the Water Division of the VADEQ. Site-specific limits may be established following receipt of initial design and estimated discharge rates of the treatment unit. This may be applicable if water generated during removal actions at OU3 and/or decontamination water generated during any remedial action conducted at the site is discharged to the WRF surface water bodies and/or adjacent surface water bodies.
	Virginia Regulations for the Control and Abatement of Air Pollution (VR 120-01-01 through VR 120-08-0605/9 VAC 5-10-10 through 9 VAC 5-80-350)	Applicable	Any emission from the disturbance of soil or water must meet the standards for the toxic pollutant particulate, and volatile organic compounds.
	Antidegradation Policy for Surface Waters (VR 680-21/9 VAC 25-260-10 et seq.)	To be considered	Surface water quality must not be degraded by discharge, except when the discharge is justifiable to provide necessary economic or social development in the area where the waters are located. Any discharge to State waters will be governed under VPDES.

TABLE 5-1 (Continued)
IDENTIFICATION OF CHEMICAL-SPECIFIC ARARs FOR SOIL FOR OU3

Authority	Requirement	Status	Requirement Synopsis
Federal Criteria, Advisories and Guidance	Toxic Substance Control Act (TSCA)	Applicable	TSCA disposal requirements are applicable if disposal of material contaminated with PCBs at concentrations of 50 ppm or greater occurred after February 17, 1978. PCBs have been detected in subsurface soil at OU3 at concentrations greater than 50 ppm; therefore this ARAR is applicable if sediments containing 50 ppm or greater are detected during the remedial actions at OU3.
State Regulatory Requirement	Virginia Solid Waste Management Regulation (9 VAC 20-80-10)	Applicable	VSWMR is also applicable for the disposal of PCB-contaminated soil and sediment.
	Virginia Hazardous Waste Management Regulation (9 VAC 20-60)	Relevant and Appropriate	This regulation sets forth criteria to determine if materials would be classified as hazardous and sets the requirements for disposal.
	Virginia Regulations for the Control and Abatement of Air Pollution (VR 120-01-01 through VR 120-08-0605/9 VAC 5-10-10 through 9 VAC 5-80-350)	Applicable	Any emission from the disturbance of soil or water must meet the standards for the toxic pollutant particulate, and volatile organic compounds.

TABLE 5-1 (continued)
IDENTIFICATION OF LOCATION-SPECIFIC ARARs FOR OU3

Authority	Requirement	Status	Requirement Synopsis
Federal Regulatory Requirement	RCRA – Location Standards (40 CFR 264.18)	Applicable	This regulation outlines the requirements for constructing a RCRA facility on a 100-year floodplain. The facility must be designed, constructed, operated, and maintained to avoid washout by a 100-year flood, unless waste can be removed safely before floodwater can reach the facility, or no adverse effects on human health and the environment would result if washout occurred. Any waste that is disposed of off-site will be placed in a regulated facility that meets these location standards and is in compliance with these regulations.
	Executive Order 11988: Floodplain Management	Relevant and Appropriate	Any activity located in a floodplain must comply with the provisions of the order. The order requires that federal activities in floodplains must reduce the risk of flood loss, minimize the impact of flood on human safety, health, and welfare, and preserve the natural and beneficial values served by floodplains. Since remedial actions are planned at OU3 that are within floodplains, this order must by complied with.
	Executive Order 11990: Protection of Wetlands (40 CFR 6, Appendix A)	Relevant and Appropriate	Federal agencies are required to minimize the destruction, loss, or degradation of wetlands, and preserve and enhance the natural and beneficial values of wetlands. All wetlands that are disturbed due to the remedial actions taken at OU3 will be restored per this order.
	Clean Water Act, Section 404 (40 CFR 230.10; 33 CFR 320-330)	Relevant and Appropriate	This regulation prohibits discharge of dredge or fill material into wetlands without a permit. It provides for the enhancement, restoration, or creation of alternate wetlands. Any wetlands disturbed due to remedial actions at OU3 of the WRF will be restored per this guidance and no fill material will be placed in the wetlands without a permit.
	Fish and Wildlife Coordination Act (16 USC 661 et seq.)	Relevant and Appropriate	Actions that will impact fish and wildlife must include action to protect affected fish and wildlife resources. The remedial actions conducted at the WRF will be coordinated with the USFWS.
	Endangered Species Act of 1973 (16 USC 1531 et seq; 50 CFR 402)	Relevant and Appropriate	This law requires that action be taken to conserve endangered or threatened species. In addition, actions must not destroy or adversely modify critical habitat. Consultation with the Department of the Interior will be established to ascertain that proposed actions will not affect any listed species.
	Migratory Bird Treaty Act (16 USC 703 et seq)	Relevant and Appropriate	Any action taken or funded which results in the killing, hunting, taking, or capturing of any migratory bird, nest, or egg is unlawful. No action will be performed at the WRF that will affect any migratory bird and/or its habitat.
	Bald and Golden Eagle Protection Act (16 USC 668 et seq)	Relevant and Appropriate	This law requires that action be taken to conserve the endangered bald and golden eagles. In addition, actions must not destroy or adversely modify critical habitat. Consultation with the Department of the Interior will be established to ascertain that proposed actions will not affect any critical habitat.

TABLE 5-1 (Continued)
IDENTIFICATION OF LOCATION-SPECIFIC ARARs FOR OU3

Authority	Requirement	Status	Requirement Synopsis
Federal Regulatory Requirement (continued)	National Archaeological and Historic Preservation Act (16 USC 469); National Historic Landmarks Program (36 CFR 65)	Relevant and Appropriate	Federal agencies must take action to recover and preserve artifacts within areas where action may cause irreparable harm, loss, or destruction of significant artifacts. Any archaeological and /or historic landmarks that may be discovered during remedial actions will be preserved per this regulation.
State Regulatory Requirement	Chesapeake Bay Preservation Act (Virginia Code Section 10.1-2100)	Applicable	Establishes criteria for land use and development in environmentally sensitive areas, which may impact water quality. These criteria are established on a statewide basis, but implemented locally. Remedial actions are being conducted near the Occoquan Bay. Therefore, these regulations may be applicable to the WRF.
	Virginia Endangered Species (Virginia Code Section 29.1-563 et seq.)	Applicable	Prohibits acts, which directly or indirectly harm, or injure a threatened or endangered species. Protects critical wildlife habitat. Any remedial action taken at the WRF will be conducted in such a manner as to assure that endangered species (if applicable) will be protected during and after the remedial action is performed.
	Virginia Department of Game and Inland Fisheries, (Code of Virginia, Section 29.1-100 et seq.)	Applicable	The Department of Game and Inland Fisheries must be notified prior to any remedial action at a site to evaluate if any rare, threatened, or endangered animal species or their habitats will be impacted by the remedial actions. The department will be notified prior to any activities that will be performed at OU3 for the WRF.
	Virginia Natural Area Preserves Act [VNAPA] (Code of Virginia Section 10.1-400 et seq.)	Applicable	The Department of Conservation must be notified prior to any remedial action to determine whether any ecologically significant area supporting natural heritage resources are threatened by the remedial action that will be conducted. The department will be notified prior to any activities that will be performed at OU3 for the WRF.
	Virginia Plant and Insect Species Act/ Virginia Plant and Insect Species Regulations (Virginia Code Section 3.1-1020 et seq./VR 115-04-01/ 2 VAC 5-320-10)	Applicable	The Department of Agriculture and Consumer Services must be notified to determine whether any rare, threatened, or endangered plant or insect species or their habitat(s) will be impacted by a remedial action that will be conducted at a site. The department will be notified prior to any activities that will be performed at OU3 for the WRF.
	Virginia Wetlands Act/ Virginia Wetland Regulations (Virginia Code Section 62.1-13.1 et seq./VR 450-01-0051/ 4 VAC 20-390-10 et seq.)	Applicable	Any activity to take place in, or impact on, a tidal wetland must meet the provisions of the Virginia Wetlands Act and regulations as applicable. Since remedial activities may be conducted in and near tidal wetlands at OU3, these regulations must be complied with.

TABLE 5-1 (Continued)
IDENTIFICATION OF ACTION-SPECIFIC ARARs FOR OU3

Authority	Requirement	Status	Requirement Synopsis
Federal Regulatory Requirement	National Pretreatment Standards (40 CFR 403)	Applicable	This regulation sets standards to control pollutants that pass through or interfere with treatment processes in publicly owned treatment works or which may contaminate sewage sludge. Any discharges generated from the remedial actions performed at OU3 where discharge to a POTW is required will be conducted such that the discharge is within the limits of the POTW's treatment standards.
	National Pollutant Discharge Elimination System (40 CFR 122 – 125)	Applicable	Permitting is required for pollutant discharge from any point source into U.S waters.
	RCRA Land Disposal Restrictions (40 CFR 268)	Applicable	Limits are mandated for characteristic and listed wastes prior to land disposal. All wastes disposed of off-site from OU3 will be disposed of at a regulated facility that is in compliance with these regulations.
	Department of Transportation Rules Governing the Transportation of Hazardous Materials (49 CFR Parts 107, 171.1-.500)	Relevant and Appropriate	Will be the responsibility of disposal organization to ensure that all waste haulers are properly registered for hauling hazardous waste and follow applicable regulations.
	Executive Order 11990: Protection of Wetlands (40 CFR 6, Appendix A)	Relevant and Appropriate	Federal agencies are required to minimize the destruction, loss, or degradation of wetlands, and preserve and enhance the natural and beneficial values of wetlands. All wetlands that are disturbed due to the remedial actions taken at OU3 will be restored per this order.
State Regulatory Requirement	VHWMR/RCRA Standards Applicable to Generators of Hazardous Waste (VR 672-10-1/9 VAC 20-60-10 et seq.)	Applicable	This regulation establishes hazardous waste identification, manifesting, transport, recordkeeping and reporting requirements. This regulation will be compiled with for the management of wastes generated through the removal actions that may occur at OU3.
	VHWMR/RCRA Standards for Permitted Hazardous Waste Facilities - Storage in Containers and Tanks (VR 672-10-1/9 VAC 20-60-10 et seq.)	Applicable	Requirements for storage of hazardous waste in containers and tanks are identified. This regulation will be compiled with for the removal actions that may occur at OU3.
	Virginia Solid Waste Management Regulations - Soil, Debris and Sludge Deposit Requirements (VR 672-20-10/9 VAC 20-80-10 et seq.)	Applicable	This law regulates "special wastes". Soil containing less than 50 ppm TPH and 10 ppm BTEX may be clean-filled. When soils with contaminants exceed this level but do not contain more than 500 ppm TPH, they may be placed in a sanitary landfill.

TABLE 5-1 (Continued)
IDENTIFICATION OF ACTION-SPECIFIC ARARs FOR OU3

Authority	Requirement	Status	Requirement Synopsis
State Regulatory Requirement (Continued)	Virginia Regulations Governing Transportation of Hazardous Materials (VR 672-30-1/9 VAC 20-110-10 et seq.)	Relevant and Appropriate	Any transportation of hazardous materials within the Commonwealth of Virginia must meet all of the requirements of these regulations as well as those outlined in Part VI and VII of the Virginia Hazardous Waste Management Regulations.
State Regulatory Requirement (continued)	Virginia Erosion and Sediment Control Law/Virginia Erosion and Sediment Control Regulations (Sections 10.1-560 et seq./VR 626-02-00/4 VAC 50-30-10 et seq.)	Relevant and Appropriate	An erosion and sediment control plan must be submitted for review by the soil and water conservation district or locality prior to engaging in any land-disturbing activity. An erosion control structure may be constructed at OU3. Therefore, this regulation will be complied with for the remedial actions that may be conducted at OU3.
	Coastal Management Plan; Federal Coastal Zone Management Act (16 U.S.C. 1451 et seq; NOAA Regulations on Federal Consistency with approved State Coastal Zone Management Programs, 40 CFR 930)	Relevant and Appropriate	Activities impacting the resources governed by these statutes must comply with state requirements.
	Virginia Pollutant Discharge Elimination System (VEPDES), (VR 680-14-01)	Applicable	Any treated groundwater, decontamination water or other wastewater to be discharged to surface waters must meet effluent discharge limits established by the Water Division of the VADEQ. Site-specific limits may be established following receipt of initial design and estimated discharge rates of the treatment unit. This may be applicable if water generated during removal actions at OU3 and/or decontamination water generated during any remedial action conducted at the site is discharged to the WRF surface water bodies and/or adjacent surface water bodies.
	Virginia Pretreatment Standards (Permit Regulation, Part VIII)	Applicable	General and categorical standards are mandated for industrial dischargers to POTW. Any water that is generated during the remedial actions conducted at OU3 will comply with these regulations if applicable

6.0 IDENTIFICATION OF GENERAL RESPONSE ACTIONS

6.1 INTRODUCTION

The OU3 risk assessments (Sections 3.0 and 4.0) evaluated potential risks to human health and ecological receptors from PCBs. The potential cumulative risks to human health were calculated to be above the USEPA risk range of 10^{-4} to 10^{-6} for future land-use scenarios. The results of ecological risk assessment indicate that there is a potential risk to ecological communities from exposures to PCBs. Therefore, a remedial action is warranted for OU3 at WRF. The remedial action objectives (RAOs) are to establish an acceptable level of risk, and attain the ARARs, established in Section 5.0.

General response actions (see Section 6.3) are broad remedial approaches capable of meeting RAOs, either alone or in combination. Different types of technologies exist within each of these general response actions. Furthermore, different process options exist within each technology type. General response actions, technology types, and process options are subjected to a screening process in Section 6.4, whose criterion is described in Section 6.2. Those passing the screening are assembled into remedial action alternatives in Section 6.5. Assembled remedial action alternatives are then screened individually in Section 7.0 and against each other in Section 8.0.

6.2 SUMMARY OF EVALUATION CRITERIA

The objective of any remedial action that is implemented to remediate the contaminated media at OU3 must satisfy the ARARs for the site and mitigate risks to human health and the environment. The list of potentially applicable technology types and process options is reduced by evaluating them with respect to implementability, effectiveness, and cost (USEPA, 1988a). Implementability measures both the technical and administrative feasibility of constructing, operating, and maintaining a technology and the ability to conduct operations safely. For the implementability criterion, the following site-specific factors are important:

- Site characteristics may inhibit the construction or effective functioning of the technology. In-situ treatment technologies and removal actions may be limited by health and safety restrictions; proximity to the facility; the area of sediment to be treated, and geotechnical characteristics of the sediment found at OU3.
- Waste characteristics may limit the use or effective functioning of the equipment. The effectiveness of specific treatment technologies may be limited by the concentrations of the PCBs or the moisture content of the sediment.
- Technology and equipment must be readily available. For any interim action, lengthy research and development of new processes is inappropriate; the technology must be implementable and the necessary equipment readily available.
- Capacity of treatment or disposal facilities must be adequate. Capacity should be sufficient to implement any treatment or disposal option.
- The need to acquire permits that are required for on-site or off-site treatment, transportation, disposal, or construction must be considered.

The effectiveness of a technology refers to its ability to permanently reduce the toxicity, mobility, or volume of the PCBs detected in the sediment. The following factors are considered under the effectiveness criterion:

- The risks to the public, workers, or the environment during construction and implementation of the technology must be considered. The potential for disturbing the sediment and, therefore, suspending the sediment particles and any attached PCBs within the surface water is also of concern when removing the sediment.
- The reliability of the technology must be considered.

- The degree of permanent reduction in toxicity, mobility, or volume of the compounds detected in the sediment must be considered. Technologies that permanently reduce the toxicity, mobility, or volume will be given preference.
- The long-term risks due to treatment residuals must be considered. Some treatment residuals could be hazardous and thus require further treatment or disposal.

Cost is considered qualitatively in the screening of process options, with only the relative magnitude of capital and operation and maintenance (O&M) costs being considered.

6.3 GENERAL RESPONSE ACTIONS

General response actions considered in the FFS for OU3 are listed in the following sections. Each of the response actions include a variety of remedial technologies. For example, ex-situ treatment technologies consist of thermal, biological, chemical, and physical treatment methods. These remedial technologies, in turn, are composed of various process options. In Section 6.4, specific process options are briefly described, evaluated, and screened on the basis of the objectives presented in Section 6.2 and in the context of their application to treatment of the contaminated media in OU3.

6.3.1 No Action

The NCP requires the evaluation of a No Action alternative as a baseline for comparison with other remedial alternatives. The No Action alternative does not involve any remedial actions. Five year reviews of site conditions would be required by CERCLA because contamination would be allowed to remain at the site.

6.3.2 Natural Attenuation/Long-term Monitoring with Institutional Controls

Natural Attenuation may reduce the volume of the PCBs detected in the soils and sediment at OU3 over time. Natural Attenuation will not reduce the toxicity, mobility or volume of contaminants present in OU3 in the immediate or near future. The mechanisms with which the volume of contaminants could be reduced include sedimentation of particles that contaminants have sorbed to, intrinsic biodegradation, and diffusion.

6.3.3 Long-term Monitoring

Long-term monitoring will not reduce the toxicity, mobility, or volume of the PCB compounds detected in OU3. Long-term monitoring activities demonstrate changes in PCB concentrations over time. The analytical data will be reviewed periodically to evaluate changes in site conditions and a report will be generated to inform both the regulators and the public of the changes in site conditions. A database of information pertaining to the site so that the public will have access to all of the recent and pertinent data pertaining to the site will be created using the data gathered from the Long-term Monitoring Program.

6.3.4 Institutional Controls

Institutional Controls will not reduce the toxicity, mobility, or volume of the PCB compounds detected in OU3. Institutional controls would be implemented and constructed to minimize the potential for human exposure to contaminants in OU3. The institutional controls would include access restrictions, land-use restrictions, and increased security. The primary advantage of this action is that neither the sediment and its associated benthic, aquatic, and vegetative communities found in the Main Ditch of OU3, nor the soils north of the Main Compound area will be disturbed. In addition, groundwater restrictions would be implemented to assure that the groundwater at OU3 is not developed as a drinking water source.

6.3.5 Removal

Removal actions would involve the removal of the sediment determined to contain elevated levels of PCBs that pose a potential risk. Removal actions, once complete, would prevent aquatic and terrestrial organisms from further contact with the sediment. A treatment technology would be conducted in conjunction with removal to provide a complete remedial action alternative.

6.3.6 Stream Construction and Restoration

The stream construction and restoration response action involves the construction of a more natural meandering stream channel in the area north of the current Main Ditch. This man-made ditch would connect the Main Ditch upstream of the confluence of the drainage swale that discharges from the Main Compound and the Main Ditch to the wetland area north of Charlie Road. The fill from the construction of the new channel would then be used to cover the portion of the ditch containing elevated levels of PCBs. This would effectively entomb the PCBs in place and minimize the potential for human and ecological exposure.

6.3.7 Ex-Situ Treatment

A variety of ex-situ treatment technologies could be designed and implemented to treat the sediment once it had been removed from the Main Ditch. Sampling activities may be included as part of this alternative to confirm that all of the sediment requiring ex-situ treatment had been removed. Ex-situ technologies involve thermal, chemical, or biological treatment of the sediment to reduce the toxicity, mobility, or volume of PCBs detected in the sediment. Treated sediment would then be placed either back on-site or transported off site.

6.3.8 In-Situ Treatment

In-situ treatment includes thermal, chemical, physical, and biological processes similar to those used in ex-situ treatment. Limited environmental monitoring activities may be required to monitor the effectiveness of a remedial action. In-situ treatment minimizes or eliminates the disturbance of the sediment and associated benthic, aquatic, and vegetative communities that would result from active removal of the sediment. In-situ treatment also minimizes the need for disposal of any ex-situ treatment residues that may remain after treatment.

6.3.9 Off-Site Treatment

This general response action involves the transport to and treatment of the excavated sediment at a permitted waste treatment facility located off-site.

6.3.10 Disposal

Disposal methods involve the ultimate placement of the excavated sediment in a permitted disposal facility such as a landfill. A landfill could either be constructed on-site or the sediment could be transported to an off-site landfill. The sediment would be sampled and subjected to a TCLP test to determine whether it would be disposed of as a hazardous or non-hazardous waste. State and Federal regulatory requirements, including land disposal restrictions (LDRs), must be considered as part of this general response action.

6.4 IDENTIFICATION AND SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS

6.4.1 No Action

The NCP requires the evaluation of a No Action alternative as a baseline for comparison with other remedial technologies. The No Action alternative does not involve any remedial actions, but may include environmental monitoring. Five year reviews of site conditions would also be required by CERCLA because the contamination would remain at the site.

Description: No Action is not a technology category; however, this alternative serves as a baseline against which all other alternatives may be compared. This response does not involve any remedial activity or institutional controls.

Initial Screening: No Action does not reduce the toxicity, mobility, or volume of contamination. However, as required by the NCP, the No Action alternative is retained for consideration in the alternatives assembly as a measure of the effectiveness of the other alternatives.

6.4.2 Natural Attenuation

Natural Attenuation takes no actions to reduce the mobility, toxicity, and volume of contaminants in environmental media. The contaminants present in OU3 make use of natural attenuation processes to reduce their concentrations. Natural attenuation is described and evaluated below.

Description: Natural Attenuation is an action in which the intrinsic biological and physical processes which occur in nature are allowed to proceed without engineered intervention. Biological processes, that could aid in the remediation of the contaminated media at OU3, include the aerobic and anaerobic degradation of organics by microorganisms which exist in soils, sediments, and water. Biological uptake of metals, and uptake and potential destruction of organics by plants and trees are also processes that will aid in the mitigation of a contaminated media. Naturally occurring physical processes, which could aid in reducing the levels of contaminated media at OU3 include volatilization of organics, migration of contaminants which leads to dilution of the contaminants, hydrolysis, photolysis, and oxidation/reduction.

Initial Screening: The natural attenuation option does not reduce the toxicity, mobility, or volume of contaminants in the short-term; however, at this site it could be combined with institutional controls to protect human health. This action is easily implemented. This action will be retained for further consideration.

6.4.3 Long-term Monitoring

A Long-term Environmental Monitoring Program would involve the periodic collection and analysis of soil, groundwater, sediment, and biota samples to monitor the change in PCB concentrations. Reports, generated after every five years of sampling, would be written and made available to both the public and the regulators to document the changes in site conditions. This alternative would also include the development and implementation of an educational program to inform the public about the site conditions. The program would also provide a database of information pertaining to the site that would demonstrate the change in site conditions over time.

Description: Monitoring programs, including periodic sampling of groundwater, surface water, sediment, and biota would allow for the evaluation of changes in contaminant concentrations over time. Surface water, sediment, soil, groundwater, and benthic analytical data, collected from locations throughout WRF as part of previous investigations and as part of the RI, have been used to complete the site characterization and risk assessments. These data would be of use in the formulation, design, and implementation of an effective Long-term Environmental Monitoring Program.

Initial Screening: Monitoring is insufficient in both preventing exposure to the PCBs detected in the sediment at OU3 and in reducing the toxicity, mobility, or volume of these compounds. Long-term environmental monitoring would be easily implemented because the required sampling equipment and protocols are well established and readily available. Long-term management efforts would also be an integral part of a Long-term Environmental Monitoring Program. Long-term environmental monitoring of the groundwater, surface water, sediment, and biota at OU3 will be retained for further consideration in the detailed analysis of the alternatives because it is an important means of defining existing contamination and monitoring the change in PCB concentrations over time.

6.4.4 Natural Attenuation/Long Term Monitoring with Institutional Controls

Establishing institutional controls at sites with reported contamination is a common practice. Typically institutional controls are easily implemented and capital costs are low. Institutional controls range from access restrictions to biota management.

Description: Institutional controls are legal or barrier restrictions on the use of land or water imposed on a site, and intended to reduce the danger to the public from exposure to contaminants at the site. Institutional controls may be used in conjunction with engineered remedial actions, or as the sole remedy. Institutional controls include such things as access restrictions, alternate

water supplies, biota management, groundwater use restrictions, and monitoring. Applicable controls to OU3 include access restrictions, in the form of fencing and signage and prohibition on unauthorized digging; and groundwater use restrictions in the form of maintaining the potable water supply and only allowing the groundwater to be used for environmental monitoring purposes.

Initial Screening: Institutional controls will not reduce the toxicity, mobility, or volume of contaminated media in OU3. If properly implemented they could be used in conjunction with a remedial action to protect human health and the environment. Institutional controls are easily implemented. Institutional controls will be retained for further consideration.

6.4.5 Stream Construction and Restoration

This general response action entails design and construction of a stream that would satisfy the flow demands of the Main Ditch and support an ecosystem similar to the one that presently exists in the Main Ditch.

Description: Stream Construction and Restoration requires research and proper design. Design requirements would include understanding the hydraulics on the site, and knowledge of the plant and animal species present in the Main Ditch. This work could be completed with traditional machinery and construction practices. Soils excavated from the new stream area would be used to cover the existing Main Ditch so that the contaminated sediments would be covered and the potential of exposure to humans and animals would be reduced significantly.

Initial Screening: Implementation of Stream Construction and Restoration would not be difficult. The effectiveness of this action would be good if the action was properly designed and constructed. Obtaining permits for the covering the Main Ditch and its banks permits for the destruction or wetlands could be difficult. The new stream area would be designed as a mitigation area for the wetland acreage destroyed. Stream construction and restoration will be retained for further consideration.

6.4.6 Removal

This general response action involves the removal of sediment containing elevated levels of PCBs, thus reducing the existing site risks associated with these compounds.

Description: Removal via excavation of the sediment from OU3 of WRF could be conducted using one of a variety of equipment. The equipment evaluated for this process option included the vacuum dredge, the vacuum truck, the clamshell excavator, and the hydraulic crawler-mounted excavator (track-hoe). Dredging equipment is quite large relative to the size of the Main Ditch; with the ditch being only three feet wide in many locations along the ditch. The vacuum truck, although ideal in that the technician, operating the vacuum truck during sediment removal, could selectively avoid the larger rocks and particles found in the ditch, was determined to have an hourly operating cost equivalent to eight times that of the operating costs of an excavator. Lastly, the clamshell excavator and the hydraulic crawler-mounted excavator (track-hoe) were evaluated for use in sediment removal at OU3 of WRF. The clamshell excavator, equipped with two hinged jaws, has an operating cost that is fifty percent higher than the costs associated with the operation of a hydraulic crawler-mounted excavator (track-hoe) when excavating wet sediment. Therefore, the use of the hydraulic crawler-mounted excavator was considered in evaluating the costs associated with sediment excavation. Sediment removed during excavation using this equipment may require subsequent sorting, dewatering, treatment, storage, and/or disposal.

Initial Screening: Excavation, when combined with storage, treatment, or disposal, would reduce the toxicity, mobility, and volume of PCBs at OU3 of WRF. Excavation equipment is readily available to remove the sediment while preventing the release of contaminants through suspension of sediment particles. Excavation involves the removal of the sediment that poses a potential risk from exposure to OU3 sediments. Excavation, using the hydraulic crawler-mounted excavator (track-hoe), is retained for further analysis.

6.4.7 Ex-Situ Treatment

Treatment methods are evaluated based on each technology's ability to treat sediment-containing PCBs. Mobile treatment units or semi-permanent units may be constructed on-site to implement physical or chemical treatment technologies once the sediment has been excavated from OU3. In-situ technologies have also been considered as addressed in Section 6.4.7.

6.4.7.1 Thermal Treatment

Thermal treatment processes (USEPA, 1988b, USEPA, 1990a) destroy or detoxify hazardous wastes in a controlled atmosphere. The hazardous compounds are converted to carbon dioxide, water, hydrogen, chloride, oxides of nitrogen, sulfur, and other combustion products when burned with excess oxygen. Thermal treatment completely destroys these compounds, reduces the waste volume, and detoxifies the waste material. High metals concentrations (including naturally occurring metals) may, however, cause adverse effects in some systems. In addition, combustion products of some heavy metals and volatile metals such as mercury are not always removed from the incinerator off-gases by air pollution control devices. Monitoring for releases of airborne compounds emitted from the thermal treatment process and inclusion of adequate pollution control systems would be designed and implemented to ensure the safe operation of the thermal treatment systems.

Vitrification

Description: Vitrification uses heat to melt the sediment. Hazardous materials are either immobilized by incorporation into a glass-like material or are destroyed by the high temperatures necessary for the vitrification process. A rigid, glassy product forms when the sediment cools. Temperatures of 1600 to 2000 degrees Celsius, needed to effectively degrade the PCBs, destroy hazardous constituents and reduce organic materials to carbon, carbon dioxide, and hydrogen. Gaseous emissions are relatively low, the resultant mass is stable, and the inorganic compounds are immobilized. The destruction mechanism is either pyrolysis (in an oxygen-poor environment) or oxidation (in an oxygen-rich environment).

Vitrification can be conducted either in-situ or ex-situ. The ex-situ vitrification process entails the use of a reaction chamber that is equipped with two different chambers in which both chambers utilize an electrical heating system. The lower chamber contains a molten zone for melts of metals and siliceous components of the waste, and the upper chamber treats off gases. Residues from the process are molten glass, molten metals, some off gases, and air pollution control device residuals.

Initial Screening: The effectiveness of vitrification for the treatment of PCB, PAH, and pesticide-contaminated sediment is difficult to assess because sampling and analysis of the glass matrix produced by vitrification is complicated; current USEPA leachability and total digestion analytical methods are not designed for a glass matrix.

The moisture content would be limited to 25 percent water by weight for effective implementation of this process. The moisture content of the sediment at OU3 ranges from 30.2 to 72.4 percent. An elevated moisture content requires an increased amount of electricity and temperature, thus requiring an increased amount of time to degrade the PCBs. Higher moisture content adversely affects treatment and contributes to a dramatic increase in cost. The cost ranges for vitrification can equal that of incineration for sediment that contains elevated moisture contents. Cement or fly ash could be blown in or mixed with the sediment using an excavator equipped with a hose line in order to reduce the moisture content. However, the sediment volume requiring treatment would be significantly increased which would eventually lead to a dramatic increase in cost.

Although this process has the potential to effectively destroy organics and to immobilize heavy metals, it has also not been used extensively to remediate these compounds. Availability of the system is limited in the United States.

Therefore, vitrification has been eliminated from further consideration.

Rotary Kiln Incineration

Description: Rotary kiln incinerators are refractory-lined cylinders that are slightly inclined from horizontal. Wastes and auxiliary fuel enter the incinerator at the upper end, and are combusted with excess oxygen. The combustion chamber rotates as wastes are combusted and move to the lower end of the unit. Mixing of wastes occurs through rotation, and this mixing allows for the complete combustion of the waste materials. Waste materials are transformed into ash and combustion gases, including carbon dioxide and water. Rotary kilns are also equipped with a secondary combustion chamber to ensure complete combustion of gases. Off-gases are treated to remove acid gases and particulates; ash (decontaminated sediment) is removed at the lower end of the unit. Residuals from this process include ash from the combustion chamber, particulates and scrubber solution from the air pollution control device, and stack gases. Scrubber solutions are generally recycled. This technology is widely available.

Initial Screening: The performance of rotary kiln incinerators performance is affected by the size and shape of the particles making up the sediment. The inorganic compounds present in the sediment samples would remain in the ash after thermal treatment. In addition, the inorganic compounds may transfer to the flue gas requiring gaseous treatment. This process has been eliminated from further consideration due to the presence of inorganic compounds in the sediment.

Infrared Incineration

Description: Infrared incineration takes place in a primary combustion chamber made of carbon steel and lined with refractory materials. Wastes are fed into the chamber on a conveyor belt able to withstand high temperatures. The wastes pass beneath a series of silicon carbide heating elements, which are electrically powered and emit infrared energy. Processed material is discharged from the furnace, while exhaust gases pass into a secondary combustion chamber which is similar in construction to the primary chamber. Auxiliary fuel or additional infrared heating elements are used to ignite any remaining combustible gases in the secondary chamber. The entire unit can be operated in an oxidizing, reducing, or pyrolytic atmosphere. Wastes generated by this process are ash, off-gases, and air pollution control device residuals. This process has been demonstrated to treat CERCLA wastes containing halogenated and non-halogenated organics including polychlorinated biphenyls, on a commercial scale.

Initial Screening: Transportable infrared systems are commercially available, but on a more limited scale than rotary kilns. The inorganic compounds present in the sediment samples would remain in the ash after thermal treatment. In addition, the inorganic compounds may transfer to the flue gas requiring gaseous treatment. This process has, therefore, been eliminated from further consideration.

6.4.7.2 Physical/Chemical Treatment

Physical treatment processes separate the PCB compounds from the sediment matrix. Physical treatment would occur after separation of non-earthen materials from the excavated materials. Chemical treatment processes chemically alter the structure of these compounds thus creating a different form of the compound and producing a waste residue where constituents may be less difficult to treat.

Chemical Oxidation

Description: Chemical Oxidation involves the addition of an oxidant. The additional oxygen that is added, in conjunction with a slight adjustment of pH (0.5 to 1.0), facilitates the desorption of the PCB compounds followed by the subsequent destruction of the carbon-oxygen bonds and any other organic bonds. The result of this modified oxidation reaction is basic elements and compounds that are non-hazardous.

The sediment is excavated and allowed to sit on the dewatering pad for a short time to allow the excess moisture to drain from the sediment (the moisture content of the excavated sediment ranges from 30 to 72 percent and the optimum moisture content of the sediment requiring treatment by chemical oxidation is 30 to 40 percent). After the excess moisture has drained or

evaporated, the sediment is screened and sorted to separate any larger pieces of debris and break up any large clumps of sediment.

The screened sediment is fed into a hopper where it is then loaded onto the main conveyor belt. A feed conveyor is located directly above the main conveyer thus allowing reagent to be applied to the sediment requiring treatment as it passes beneath on the main conveyor belt. The oxidant reagent is allowed to act on the sediment before the sediment/reagent mixture is processed into the mixer. The reagent, sediment, and water are thoroughly mixed allowing the reagent to disperse throughout the entire sediment mixture and thus allowing the reagent to act on all soil particulate faces to desorb and degrade the PCBs. Treated sediment is slowly and continually pushed from the mixer as sediment requiring treatment is dropped into the mixer from the main conveyor belt.

The sediment, discharging from the mixer, is either deposited on the ground or put into loaders for stockpiling. The sediment that has been either deposited on the ground or stockpiled is allowed to sit for a period of 24 hours. After 24 hours has elapsed, the sediment is sampled to confirm that the PCBs have been reduced to levels that meet regulatory requirements for the protection of human health and the environment. These confirmatory samples also assure that the treated sediment does not contain any other hazardous compounds.

Initial Screening: Chemical oxidation using the reagent termed MP-5000 (oxidant) has been used to treat soil and sediment material in California, Texas, Ohio, Pennsylvania, New York, and Wisconsin (ASI, 1996). Calcium, sodium, potassium, magnesium, and aluminum salts may be generated during the oxidation process. The salts, resulting from the mineral balance, have not, however been detected in excess of the level of concern. Treatment using chemical oxidation, an experimental technology, will be retained for further analysis in the detailed analysis of alternatives based on its merit as an innovative technology. Chemical oxidation treatment of PCBs holds promise as a potential remedial alternative because it may be a cost-effective means of treating the sediment as opposed to transporting the sediment off-site for disposal.

Solvent Extraction

Description: Solvent extraction does not destroy wastes, rather it is a physical means of separating the PCB compounds from the sediment. This process makes the use of a solvent to separate these compounds from sediment particles by partitioning the compounds from the sediment to the solvent (USEPA, 1988b). Solvents are mixed with the sediment at low temperatures and a high pH, and then centrifuged or filtered to separate the extracted materials from the liquid-phase. Solids are then dried to recover the solvent, which may be recycled. The resulting liquid-phase solution is heated, which breaks emulsions and separates the organic and aqueous phases. This two-phase solution is then decanted, removing the organic/solvent-rich top fraction.

Initial Screening: Both the liquid-phase and the solid-phase material, resulting from solvent extraction, require further treatment in separate stripping columns and possibly further distillation or further refinement. Pre-treatment is also commonly required before solvent addition. In order to be cost-effective, acceptable wastes must contain higher than 200 mg/L organics, which is much larger than what has been detected in the sediment at OU3 of WRF. This process option has been successful in the treatment of PCB-contaminated soil, and has the potential to successfully remove other organic constituents. However, this remedial technology requires extensive pre-treatment and post-treatment, therefore, this alternative has been eliminated from further consideration.

Sediment Washing

Description: Organic particles may be adsorbed to sediment particles. These compounds are "washed" from the sediment using a liquid medium such as water with the aid of a surfactant (USEPA, 1994d). Organic solvents, water/chelating agents, water/surfactants, acids, and bases may also be used to extract the PCBs. The principal components of the process include pre-treatment equipment for particle sizing, a truck-mounted soil washer for the larger soil particles,

and a sediment wash unit for the smaller particles. Water treatment and reconditioning equipment are also included. The soil washing systems, for larger particles, consist of a trailer-mounted gondola constructed with aeration devices to aid in mixing, water/chemical addition, oil skimming, and liquid drainage. The sediment washing system consists of a shaker screen (large particles are diverted to the soil washer described above) that is a pre-treatment unit where a slurry is created. The sediment particles, after having been fed to a hopper, are then sent to the sediment cleaning chamber where the PCBs are desorbed from the smaller sediment particles (typically clay material). The slurry then flows into the scrubber followed by the buffer tank where the larger particles are separated. The remaining clay particles are further treated in a hydrocyclone and centrifuge. Eventually all of the clean solid particles are separated out and the washwater is treated in a conventional wastewater treatment system. The decontaminated water is then recycled back through the system by being incorporated into the system during the slurry phase. This process has been demonstrated to effectively treat soil containing many inorganic compounds, volatile and nonvolatile hydrocarbons, chlorinated hydrocarbons, pesticides, polychlorinated biphenyls, polycyclic aromatic hydrocarbons, and most organic compounds.

Initial Screening: This treatment technology has not been used extensively to treat sediments containing TPH and PCBs (Saber et al., 1995). The use of biosurfactants for the desorption of hydrophobic organic compounds such as TPH and PCBs from the sediment particles is currently being researched and evaluated (Grey et al., 1995). This treatment technique has been eliminated from further consideration under the detailed analysis of alternatives because of its limited use, the limited availability of information pertaining to the types of surfactant that effectively mobilize these compounds, and the fact that the additional waste stream water must be treated using carbon adsorption.

Solidification/Stabilization

Description: Waste stabilization involves the addition of a binder such as Portland cement, cement, kiln dust, or fly ash to a waste material to convert the contaminants into a less soluble, mobile, or toxic form. Waste solidification, on the other hand, involves the addition of a binding agent such as Portland cement or asphalt, to the waste to encapsulate the PCBs into a solid material. Solidifying the sediment improves the materials handling characteristics and reduces permeability to leaching agents by reducing waste porosity and exposed surface area.

Initial Screening: Solidification and stabilization of the sediment would not concentrate or destroy the PCBs rather the compounds would become immobilized. This alternative was not retained for further analysis in the detailed analysis of alternatives because efforts are not undertaken to reduce the volume or toxicity of the PCBs.

6.4.7.3 Biological Treatment

Biological treatment utilizes indigenous or non-indigenous microorganisms to biologically degrade organic compounds. During biodegradation these compounds are broken down and heat is generated as part of the microbial metabolism. Bacteria, fungi, and yeast can degrade these compounds under aerobic and anaerobic conditions. The by-products, generated under anaerobic conditions include methane, carbon dioxide, and cell protein. Solid-phase (composting) and slurry-phase (aerobic and anaerobic bioslurry) treatment processes have been developed for a wide-range of organic compounds.

Composting

Description: In composting systems, waste material is mixed with bulking agents and amendments such as wood chips, straw, or manure. Amendments provide nutrients for the microorganisms, while bulking agents alter the physical composition of the compost material to make it more aerobic. The compost mixture is then placed in a controlled environment where temperature, nutrients, and oxygen can be controlled. Gaseous emissions and leachate can also be collected and treated. Static pile composting, the most simplistic method of composting, involves placing the compost material in a static pile and allowing it to self-heat. Compost piles can also be formed into long windrows where they are mixed with a mechanical turner. Controlled static pile composting incorporates the placement of perforated pipes under the

compost pile in order to aerate and/or heat the piles. Air is drawn or forced through the piping to aerate the pile and control heating. The most complex level of composting technology is termed mechanically agitated in-vessel (MAIV) composting. An automated material handling system feeds soil into an enclosed vessel where the soil is composted. MAIV composting is a continuous process that decreases the time required for biodegradation by carefully controlling the composting environment. The MAIV process includes materials handling, aeration, and temperature control (USAEC, 1988; USAEC, 1991; USEPA, 1990a; USAEC, 1993).

Initial Screening: An increased sediment volume would require a large quantity of amendment and bulking agents to render the sediment/amendment/bulking agent mixture suitable for composting due to the high moisture content of the sediment. In addition, bulking agents used in composting may sorb the PCBs thus binding them to the bulking agent. This would consequently lead to false conclusions pertaining to the effectiveness of treatment. This alternative has been eliminated from further consideration in the detailed analysis of alternatives because of the extensive dewatering and increased bulking agent/amendment required to compost the sediment at OU3.

Aerobic Bioslurry

Description: Aerobic bioslurry reactors are batch treatment systems that reduce biodegradable organic compounds in a controlled environment. Aerobic bioslurry treatment enhances the degradation of organic compounds using microorganisms either indigenous or inoculated to the sediment. These systems are different from other biological treatment technologies because the systems are capable of increasing the degradation rate of these compounds by increasing the availability of the PCBs, cometabolites, electron acceptors, nutrients, and other additives to the microbial consortia. This is accomplished by completely mixing the sediment in a water slurry (typically at 40 percent solids), thereby reducing mass transfer limitations associated with biotreatment of the sediment. Aerobic bioslurry systems maintain oxygen levels by diffusion of air or oxygen into the slurry. The result of the operational features is a biological system that is conducive to optimal microbial activity and increased degradation rates (Brown et al., 1995; Fredrickson, 1996; Gunnison, 1996; Harvey, 1996; Zappi et al., 1993; and Zappi et al., 1994). Small quantities of amendments and no bulking agents are required.

Initial Screening: The estimated cost of applying this technology is 90 to 300 dollars per cubic yard (Gunnison, 1996 and Zappi et al., 1994). This technology, an emerging technology for the treatment of PCBs, has been retained for further analysis in the detailed analysis of alternatives based on its merit as an innovative technology.

Anaerobic Bioslurry

Description: Anaerobic bioslurry treatment is similar to aerobic bioslurry treatment in that the biodegradation of the sediment is performed in a controlled environment, but the anaerobic process is performed in the absence of oxygen (Brown et al., 1995; Fredrickson, 1996; Gunnison, 1996; Harvey, 1996; Zappi et al., 1993; and Zappi et al., 1994). As with the aerobic bioslurry system, the environmental parameters such as pH, temperature, and nutrients could be monitored and optimized in the batch process to increase the biodegradation rate of organic constituents. Anaerobic bioslurry reactors are designed to prevent oxygen from entering the reactor. A treatability study would be conducted as the initial part of the remedial design to both initially determine and further refine the operational parameters such as slurry time. The optimum operational parameters are highly site specific; therefore, it is imperative to conduct a treatability study prior to final design.

Initial Screening: Research and laboratory studies have indicated that anaerobic bioslurry treatment is an effective means of degrading PCBs; therefore, this alternative has been retained for further analysis based on its merit as an innovative technology (Brown et al., 1995; Fredrickson, 1996; Gunnison, 1996; Harvey, 1996; Zappi et al., 1993; and Zappi et al., 1994).

Phanerochaete chrysosporium (White Rot Fungi)

Description: Phanerochaete chrysosporium (white rot fungi) has demonstrated effectiveness in degrading aromatic environmental pollutants such as PAHs and PCBs through the generation of a carbon center free radical enzyme system (Field et al., 1995 and Holyrod et al., 1995). The white rot fungus cannot be directly inoculated onto the soil or sediment requiring treatment because this fungus does not thrive in such an environment. Rather, the fungus must be pre-grown on a sterile substrate and then mixed with the sediment or soil before treatment is initiated. The white rot fungus was inoculated and pre-grown on a mixture of straw, wood chips, sawdust, and pine bark. The inoculated mixture was maintained at a certain moisture content while allowed to grow beneath a High Density Polyethylene (HDPE) lining. Once the white rot fungus was thriving in the wood chip and amendment mixture, the excavated soil was uniformly mixed with the wood chip mixture. The excavated soil/inoculated wood chip mixture was then spread over a gravel base enclosed in HDPE. The treatment beds were aerated with blowers and leachate was collected in a collection tank. The collected leachate was soaked in peat and reapplied to the treatment bed. This treatment technique was effective in bioremediating the 6400 cubic meters of soil containing elevated levels of crude chlorophenol. The white rot fungus has also been used to remediate sites in Oshkosh, Wisconsin and Brookhaven, Mississippi.

Initial Screening: This treatment technique, although used for the remediation of soil containing elevated levels of PAHs and PCBs, has not been used extensively for soil or sediment remediation (Field et al., 1995 and Holyrod et al., 1995). The increased moisture content of the sediment may cause a problem when bioremediating the sediment through the introduction of a pre-grown white rot fungus and straw, wood chips, sawdust, and pine bark amendments. Leachate generation might also be excessive. In addition, this treatment technique has been used to treat soil containing 100 to 200 parts per million chlorinated phenols which is much greater than the concentrations of PCBs at OU3. Therefore, this treatment technology has been eliminated from further consideration in the detailed analysis of alternatives.

6.4.8 In-Situ Treatment

In-situ treatment technologies offer the advantage of treating sediment without the prerequisite of removal. Methods that apply to sediment have been developed. However, many of these methods have not been proven to be effective.

Phytoremediation

Description: Phytoremediation is the use of plants to remediate soil, sediment, or water containing elevated levels of organic and inorganic compounds. Other terms that refer to phytoremediation include biomining, phytoextraction, phytostabilization, phytoabsorbtion, phytosequestration, phytolignification, phytodegradation, green remediation, and botano-remediation. The success of phytoremediation varies depending upon the type of compounds requiring remediation. The effectiveness of plant-based remedial technologies is highly dependent on the lipophilicity of the compound, the amount of organic material naturally present in the soil, and the amount of water that a specific root material will uptake. Not all compounds are equally accessible to plant roots in the soil environment because the plant roots only absorb organic pollutants at a rate directly proportional to the relative lipophilicity of the compound. Once the pollutant has been absorbed by the plant roots it can either be sequestered in the root tissue, metabolized in the root tissue, or transported from the root out into the shoot. An additional source of increased metabolic capacities in the plant-based systems exists within the microbial communities that live both within the plant and attached or adjacent to the root network. The uptake of organic and/or inorganic pollutants is primarily dependent on the stage of plant growth.

The remediation of PCBs using phytoremediation is currently being researched. Research pertaining to the phytoremediation of PCBs has indicated that the use of either flavonoid or coumarin compounds (produced by the plants) and root leachate from Mulberry trees enhances and sustains the existence of PCB-degrading bacteria which will in turn degrade the compound.

The advantages of phytoremediation are low input costs, soil stabilization, and the fact that it is aesthetically pleasing as excavation is not required. The costs of this alternative are associated with planting, maintaining plant growth (fertilization and watering), harvesting, disposal of the plants once the organic and inorganic compounds have been concentrated in the biomass, and repeating the plant growth cycle.

Initial Screening: Phytoremediation is economical and passive although it may require 20 years to reduce the levels of organic and inorganic compounds to the remediation goal. The limitations of phytoremediation are that the plant must be able to grow in the sediment area where PCBs were detected. The plant can only accumulate the PCBs that it can reach through root growth with the roots only extending as deeply as necessary to acquire food and water. In addition, the roots, a living material, have significant environmental limitations for pH, temperature, osmotic pressure, moisture, and oxygen. Roots also require oxygen for respiration; hence they do not tend to grow into the anaerobic zones. Many sites containing elevated levels of biodegradable organics tend to become anaerobic due to microbial activity. Research pertaining to the phytoremediation of organics, currently in its infancy, has been preliminary and suggestive, rather then definitive on producing results that indicate that these plants will reduce the PCB, PAH, and pesticide concentrations to within acceptable levels. Therefore, this alternative has been eliminated from further consideration in the detailed analysis of alternatives.

In-Situ Vitrification

Description: Sediment requiring treatment is melted in place in order to bind the PCBs into a glassy, resistant, solid matrix form. Electrodes are installed into the media and conductive material is placed between them to aid in the electrical conductance. Electrical current is transferred to the surrounding sediment and the sediment is melted, incorporating the nonvolatile compounds. Organic compounds are pyrolyzed and the by-products travel to the vitrified surface where they combust. A hood is placed over the area requiring treatment in order to trap any volatiles that may be generated. Inorganic compounds are trapped within the vitrified mass. The presence of shallow groundwater or perched water may cause complications in the system. Fly ash or lime may be mixed with the sediment prior to the use of in-situ vitrification if the moisture content is high.

Initial Screening: The presence of perched water may cause complications in the system. The use of in-situ vitrification has only been conducted by one vendor and it has not been used extensively (USEPA, 1993). Therefore, this alternative was not further evaluated for treatment of the sediment at OU3 at WRF.

Microbial Mats

Description: Remediation using microbial mats involves the use of either free floating biomass or a mat consisting of the biomass pre-grown on an inert substrate. The microbial free-floating biomass or the microbial biomass that has been pre-grown on the inert substrate mat can be used to degrade PCBs or chlordane in sediments (Bender et al., 1995). The microbial mats, which must be acclimated to the environment, consist of a mixture of cyanobacteria (blue-green alga and a bacterium consortium (Bender et al., 1995). The mats appear to be effective in degrading PCBs and other chlorinated organics because they offer a combination of microbes that spontaneously generate both anoxic and oxic zones for microbial degradation.

Initial Screening: The use of microbial mats is an innovative treatment technology that has recently been developed. The microbial mats have been researched in the laboratory and are currently being field tested for the treatment of manganese and iron resulting from coal tar drainage. The microbial mats have been demonstrated to effectively treat PCBs and other chlorinated organics in the lab, but this technology has not been tested at the pilot-scale level. This technology has not been evaluated further in the detailed analysis of alternatives because of information is currently not available pertaining to the successful use of this technology for a field-scale remediation project.

6.4.9 Off-Site Treatment

Description: Sediment removed from OU3 could be treated at a permitted off-site incinerator. Excavated materials would be transported and treated at an appropriate facility. Analytical data indicating the constituency of the waste would be required upon delivery of the sediment requiring treatment. Incineration would permanently reduce the toxicity, volume and mobility of the PCBs found in the sediment.

Initial Screening: Incineration at an off-site facility would be very costly due to the permitting and facility fees. This alternative is similar to on-site incineration, with the exception that permitting and public acceptance concerns would not have to be considered. Although off-site incineration would permanently reduce the toxicity, volume, and mobility of the PCBs, the costs incurred are not competitive for larger quantities. This alternative has been eliminated from further consideration in the detailed analysis of alternatives presented in Section 7.0.

6.4.10 Disposal

Options for disposal of the sediment and/or treatment residuals would be necessary only in cases where removal was implemented. If the treated sediment passes TCLP tests and does not contain any listed hazardous materials in excess of levels that are protective of human health and the environment, indicating that the material is not a hazardous waste, it could be disposed of as a solid waste. If the sediment could be treated to the extent that regulators would consider acceptable, then it could be backfilled on-site. Disposal options, although very different, can be implemented for untreated sediment excavated from the Main Ditch and the sediment treatment residuals.

6.4.10.1 On-Site Landfill

Description: An on-site landfill could be designed and permitted for the disposal of materials at WRF according to either RCRA Subtitle C or Subtitle D Guidelines and the State of Virginia Solid Waste Regulations. The requirements of Subtitle D and/or Subtitle C of 40 CFR 210-220 and the State of Virginia concerning the siting, design, construction, closure, and post-closure care of facilities would have to be met. The potential liability associated with off-site transport is eliminated.

Initial Screening: The use of an on-site landfill would require the design, construction, closure, and post-closure care of facilities which must meet all substantive requirements of Federal and State solid waste regulations. Because of the construction, operation, and closure of an on-site landfill would be costly and maintain a high level of long-term liability, on-site landfilling is eliminated from further consideration.

6.4.10.2 Off-Site Landfill

Description: An off-site solid waste (RCRA Subtitle D) or hazardous waste (RCRA Subtitle C) facility could be utilized for sediment disposal, depending on the nature of the excavated materials. Analytical data collected from the sediment would be required upon delivery of the sediment.

Initial Screening: This process option could effectively immobilize the waste materials, but would be difficult to implement and costly. Sediment containing inorganic and organic compounds, which fails the TCLP test, would have an associated toxicity. Therefore, this sediment would require off-site disposal as a hazardous waste. If the sediment material did pass the TCLP test it would be disposed of as a non-hazardous solid waste. Transportation required for off-site disposal would increase the short-term risks because of the increased probability of an accident and subsequent public exposures. This alternative has been retained for further consideration in the detailed analysis of alternatives as a measure of cost comparison between on-site treatment alternatives and off-site disposal.

6.4.11 Backfill Treated Sediment

Description: Sediment could be backfilled into the excavated space after treatment, provided that the sediment is treated to within levels that meet the established regulatory requirements

that are protective of human health and the environment. This option could be implemented following ex-situ treatment, provided the proper sediment and erosion control measures are in place. Analytical data would be collected to confirm the sediment has been treated.

Initial Screening: This option is a viable option if the sediment is adequately treated on-site. Therefore, this option has been retained for further analysis in the detailed consideration in the detailed analysis of alternatives.

6.5 SUMMARY OF REMEDIAL TECHNOLOGY SCREENING

Remedial Action Alternatives are developed from the remedial technologies and process options that passed the initial screening in Section 6.4. The alternatives are described briefly below and are described in detail in Section 7.0. The No Action Alternative is defined by one general response action. The other alternatives are defined by a combination of general response actions, remedial technologies, and process options. Long-term monitoring and institutional controls will be included with Alternatives B-F because of regulatory requirements.

- Alternative A: No Action;
- Alternative B: Natural Attenuation/Long-term Monitoring with Institutional Controls;
- Alternative C: Excavation/Ex-situ Treatment using Chemical Oxidation/On-site Placement/ Long-term Monitoring/ Institutional Controls;
- Alternative D: Excavation/ Bioslurry Treatment/ On-site Placement/ Long-term Monitoring/ Institutional Controls;
- Alternative E: Stream Construction/Stream Restoration/Long-term Monitoring/Institutional Controls; and
- Alternative F: Excavation with Off-site Disposal in a Landfill/Long-term Monitoring/ Institutional Controls.

7.0 DETAILED ANALYSIS OF ALTERNATIVES

This section presents the detailed analysis of remedial alternatives that were retained based on the initial screening of remedial technologies presented in Section 6.0.

7.1 NINE EVALUATION CRITERIA

Excerpted below area the nine NCP evaluation criteria (40 CFR 300.430(e)(9)(ii)) that encompass statutory requirements, technical evaluation, cost, and institutional considerations. Of these nine criteria, only the first seven will be evaluated in this report. The last two criteria, State Acceptance and Community Acceptance will be evaluated after the State regulators and the community members have had a chance to review and comment on the Proposed Plan. The detailed criteria are as follows:

1. Protection of human health and the environment;
2. Compliance with ARARs;
3. Long-term effectiveness and permanence;
4. Reduction of toxicity, mobility, or volume through treatment;
5. Short-term effectiveness;
6. Implementability;
7. Cost;
8. State acceptance; and
9. Community acceptance.

Protection of human health and the environment and compliance with ARARs are "threshold criteria" which must be met by the selected remedial action unless a waiver can be granted under Section 121(d)(4) of CERCLA. Criteria 3 through 7 are "primary balancing criteria", and the trade-offs within this group must be balanced. The preferred alternative will be the alternative which is protective of human health and the environment, is ARAR compliant, and provides the best combination of primary balancing attributes. The final two criteria, State and Community acceptance, are "modifying criteria" which are evaluated following the comment period on the Proposed Plan.

7.1.1 Protection of Human Health and the Environment

A determination and declaration that this criterion will be met by the proposed remedial action must be made in the Record of Decision (ROD); therefore, this is a threshold criterion that must be met by the selected remedy. This criterion will be met if the potential risks posed by the site are eliminated, reduced, or controlled through treatment, engineering, or institutional controls, and if the remedial action is protective of the environment. In the case of WRF, the proposed remedial action will be made in a Decision Document.

7.1.2 Compliance with Applicable or Relevant and Appropriate Requirements

Compliance with ARARs is also a threshold criterion that must be met by the proposed remedial action. The ARARs identified in Section 5.0 are grouped in the following categories: chemical-specific, location-specific, and action-specific requirements. In general, the ARARs that are relevant to this remedial action apply to the performance of the action as well as mandating site cleanup to meet promulgated requirements. Therefore, the remedial action must be performed and monitored to ensure compliance with ARARs. The cleanup goal for the remediation of the PCB-contaminated sediments at OU3 is 1.0 ppm PCB.

7.1.3 Long-term Effectiveness and Permanence

The ability of the remedy to satisfy the remedial action objectives in the long-term was considered. Components of this analysis included the following:

- The expected long-term reduction in risk posed by the site;

- The level of effort needed to maintain the remedy and monitor the area for changes in site conditions; and
- The compatibility of the remedy with other planned actions at the site.

7.1.4 Reduction of Toxicity, Mobility, or Volume through Treatment

This criterion addresses the statutory preference for remedial technologies that significantly and permanently reduce the toxicity, mobility, or volume of the compounds detected in the contaminated media. The following factors were considered:

- The amount of materials requiring treatment or disposal;
- The degree of expected reduction in toxicity, mobility, or volume;
- The degree to which the benefits of the remedial action would be irreversible; and
- The types and quantities of treatment residuals that would remain following treatment.

7.1.5 Short-term Effectiveness

The short-term effects to human health, resulting from remedial activities associated with the construction, implementation, operation and maintenance, and upon completion, were addressed under this criterion. The following factors were considered:

- Protection of the community during the remedial action, including the effects of potential releases from the site, off-site transport of materials removed from the site, and air-quality impacts from on-site treatment;
- Protection of workers during the remedial action;
- Environmental impacts of the remedial action; and
- Time required to achieve remedial response objectives.

7.1.6 Implementability

The technical and administrative feasibility of implementing the remedial action was addressed. The technical feasibility was evaluated on the basis of ease of construction and maintenance, reliability of the selected technology, and the ease of coordinating the technology with remedial actions for other operable units at WRF. The administrative implementability was evaluated based on the relative ease of coordinating and obtaining approval for the remedial alternative with regulatory agencies.

7.1.7 Cost

The capital costs, operating and maintenance costs, and present worth of each remedial action were estimated. In addition, the accuracy of the cost estimates was considered. A relatively large contingency was included in all of the cost estimates to account for the unknown risks that would be present during implementation.

7.1.8 State Acceptance

Assessment of State concerns may not be completed until comments on the FFS are received but may be discussed, to the extent possible, in the Proposed Plan issued for public comment. The state concerns that shall be assessed include the following:

- State's position and key concerns related to the preferred alternative and other alternatives,
- State's comments on ARARs or the proposed use of waivers.

7.1.9 Community Acceptance

This assessment includes determining which components of the remedial alternative interested persons in the community support, have reservations about, or oppose. The assessment may not be completed until comments on the Proposed Plan are received.

7.2 DETAILED ANALYSIS OF ALTERNATIVES

7.2.1 Alternative A: No Action

7.2.1.1 Description

The No Action Alternative, included as part of the detailed analysis of alternatives presented in this section, is intended to serve as a baseline with which to compare the risk reduction effectiveness of the remaining five alternatives that have been considered and are presented in the detailed analysis of alternatives. The potential risks to human health and/or the environment would not be actively reduced, controlled, or monitored as part of the No Action Alternative. Because of requirements under CERCLA, a report must be generated every five years reporting conditions at this site. The cost of this required reporting will be included as part of this alternative.

7.2.1.2 Overall Protection of Human Health and the Environment

The U.S. Army plans on transferring the WRF property to the USFWS for use as a wildlife refuge. The human health and ecological risk assessments identified that the sediment contains levels of PCBs that may pose potential adverse effects to human health and/or the environment. The No Action alternative would not satisfy the criterion of protection of human health and the environment because the PCBs would continue to persist in the environment once the property had been transferred. Efforts would not be made to protect the wildlife refuge environment or the human population that may have access to that wildlife refuge.

7.2.1.3 Compliance with Applicable or Relevant and Appropriate Requirements

The chemical-specific ARARs pertaining to the levels PCBs detected in the sediment is the USEPA clean-up goal of 1.0 ppm for PCB-1260. The No Action Alternative would not comply with the ARAR because active measures would not be undertaken to reduce the levels of PCBs detected in the sediment. In addition, measures would not be taken to protect human health or the environment.

7.2.1.4 Long-term Effectiveness and Permanence

Measures would not be undertaken to reduce, control, or monitor the levels of PCBs detected in the sediment. The concentrations of PCBs may be reduced over an extended period of time due to natural attenuation. This alternative may be effective over the long-term; however, measures would not be taken to reduce, control, or monitor the risks in the short term. Human health and/or the environment would continue to be exposed to these potential risks for many years until the PCB naturally attenuate to within levels that do not pose a risk. Therefore, the long-term effectiveness of the No Action Alternative is uncertain.

7.2.1.5 Reduction of Toxicity, Mobility, or Volume through Treatment

The No Action Alternative would not involve active removal and/or treatment of the sediment; therefore, the toxicity, mobility, or volume of the PCBs detected in the sediment would not be reduced as part of this alternative. In addition, the planned future usage of the WRF facility coupled with the extensive existing and future development that is occurring in the areas surrounding WRF, may not allow the No Action Alternative to be a viable alternative.

7.2.1.6 Short-term Effectiveness

There would not be any short term risks to workers at WRF or to the local community associated with the No Action alternative because remedial activities would not be conducted at the site to reduce, control, or monitor the levels of PCBs at the site. In addition, the No Action Alternative would have zero impact on the wetland or its associated ecosystem.

7.2.1.7 Implementability

There would not be any implementation concerns associated with the No Action Alternative because activities would not be implemented at the site.

7.2.1.8 Cost

An annual O&M cost of $7200 is estimated for this alternative based on the reporting requirements. The present value for this alternative calculated using a 5% interest rate and a life of 30 years is $109,795.

7.2.1.9 State Acceptance

State acceptance will be addressed in the Decision Document.

7.2.1.10 Community Acceptance

Community acceptance will be addressed in the Decision Document.

7.2.2 Alternative B: Natural Attenuation/Long-term Monitoring with Institutional Controls

7.2.2.1 Description

This alternative would include implementation of the following actions:

- Development of both a public education program and a database program of pertinent data;
- Institutional controls;
- Long-term Environmental Monitoring Program; and
- Long-term Management.

Public education programs and a database of recent and pertinent site data would allow the public to be continually informed about the site as the PCBs naturally attenuate.

The institutional controls, to include access restrictions, deed restrictions, land-use restrictions, and increased security, would be implemented to prevent human contact with the sediments and aquatic community within the Main Ditch.

The Long-term Environmental Monitoring Program for the WRF facility would include sampling of sediment, surface water, and biotic indicators to monitor the natural attenuation of PCBs over time. Groundwater samples would also be collected to assure that PCBs have not migrated into the shallow groundwater system at WRF. The PCBs are relatively stable and do not dissolve easily in water. In addition, these compounds may bioaccumulate and therefore persist in the environment for years. Therefore, groundwater samples would be collected annually and surface water, sediment, and biota samples would be collected every five years for a period of thirty years to monitor the extent of natural attenuation. A report would also be generated every five years, per the requirements of CERCLA, to indicate the recent site conditions and the extent of natural attenuation. If the sampling indicated an increase in the potential risk to human health or the environment, recommendations would be made to actively remediate the site.

The Long-term Management of this alternative would require coordination with the USFWS, because the U.S. Army has plans to transfer the WRF facility to the USFWS for use as a wildlife refuge.

7.2.2.2 Overall Protection of Human Health and the Environment

Natural Attenuation/Long-term Monitoring with Institutional Controls would not include any further actions to actively reduce/eliminate the PCBs. This alternative would allow for the natural attenuation of the PCBs, but would provide for a minimal reduction in adverse effects to the aquatic and terrestrial environments and/or human health in the immediate future, as the natural attenuation of these compounds requires many years. This alternative is advantageous because ancillary disturbances of the wetlands would be minimized by either limiting future use/development of the affected area through deed and land-use restrictions or by not actively removing and treating the sediment. Therefore, this alternative may be effective in reducing the potential risks to human health and the environment over the long-term while minimizing destruction of the natural environment in the short-term. Long-term monitoring would be a necessary component of this alternative.

7.2.2.3 Compliance with Applicable or Relevant and Appropriate Requirements

The Natural Attenuation/Long-term Monitoring with Institutional Controls alternative may allow for the reduction of PCBs in the long-term. The compounds, being relatively stable in the environment, hydrophobic, and capable of bioaccumulating, would not naturally attenuate for a number of years.

The active components of this alternative include the development of a public education program and database of information, implementation of institutional controls, long-term monitoring, and long-term management. All active components of this alternative would be conducted in compliance with all action-specific and location-specific ARARs.

7.2.2.4 Long-term Effectiveness and Permanence

The PCB concentrations would most likely decline over the long-term due to natural attenuation. In addition, the source areas for the PCBs have been removed and, therefore, no additional contaminant loading should occur. This alternative would include the implementation of a long-term environmental monitoring program to evaluate the effectiveness of natural attenuation. If the analytical data indicates that these compounds are not naturally attenuating and the potential risk to human health and the environment is not being reduced, then efforts will be undertaken to actively reduce the levels of PCBs, detected in the sediment at OU3.

7.2.2.5 Reduction of Toxicity, Mobility, or Volume through Treatment

The toxicity, mobility, or volume of the PCB compounds, detected in the sediment at OU3, would not be reduced in the short term if Alternative B were implemented. This alternative does not include tasks, which would remove and/or treat contaminated sediments. The toxicity, mobility, or volume of PCBs may be decreased over the long-term as these compounds attenuate naturally.

7.2.2.6 Short-term Effectiveness

There would not be any short-term impacts to workers at WRF or to the local community during the development and implementation of the Natural Attenuation/Long-term Monitoring with Institutional Controls alternative which would result from the active removal and treatment of the sediment. In addition, short-term impacts to the wetland, aquatic, and terrestrial environments would be minimized.

7.2.2.7 Implementability

Each component of the Natural Attenuation/Long-term Monitoring with Institutional Controls alternative is feasible and could be easily implemented at OU3. The necessary equipment and materials required for implementation of this alternative are readily available. Implementation of this alternative would require coordination between the U.S. Army, the USFWS, the State of Virginia, and the USEPA to ensure continuity in the implementation and maintenance of all aspects of long-term management and monitoring associated with this alternative. Implementation of this alternative would not have any effect on the additional future actions planned at the WRF.

7.2.2.8 Cost

The estimated costs associated with the Natural Attenuation/Long-term Monitoring with Institutional Controls alternative are presented in Tables B-2 and B-3 in Appendix B. Capital costs are estimated to be $33,861 and annual O&M costs are estimated to be $17,865. Total present worth costs for this alternative based on a 30 year (5% discount rate) implementation period are estimated at $308,491(refer to Table B-12, Appendix B). Contingencies associated with this alternative would be minimal because this alternative does not include any treatment or design components.

7.2.2.9 State Acceptance

State acceptance will be addressed in the Decision Document.

7.2.2.10 Community Acceptance

Community acceptance will be addressed in the Decision Document.

7.2.3 Alternative C: Excavation/Ex-Situ Treatment using Chemical Oxidation/On-Site Placement/Long-term Monitoring/Institutional Controls

7.2.3.1 Description

The risk assessments indicated that the concentration of PCB-1260 in the Main Ditch of OU3 was detected at levels which may adversely effect the aquatic and terrestrial communities. Figure 7-1 presents the location of the area where PCB-contaminated sediment would be removed for the proposed remedial action. The sediment in the ditch and wetlands, containing levels of PCBs that may adversely effect human health and/or the environment, would be removed and treated using chemical oxidation. The treated material would then be placed back on site. This sediment would not be placed back on-site until confirmatory sampling was conducted to assure the effectiveness of treatment (i.e. meet clean-up goals). The costs associated with the removal of one foot of sediment over the entire surface of the PCB-contaminated area have been estimated as part of this analysis.

The sediment would be excavated and staged on the dewatering pad to eliminate excess moisture. The sediment would subsequently be sorted to eliminate any large pieces of debris and to break up any large clumps of sediment. Chemical oxidation treatment does not require that the sediment be completely dried because it would be fed into the treatment system in a moist form.

This alternative would also include the restoration of vegetation that was naturally present in the ditch areas prior to excavation. This should foster the redevelopment and long-term viability of the benthic and aquatic communities.

Site Preparation

An area in vicinity of the PCB contaminated sediments clear of trees and other tall vegetation would be used as a staging area. The best area would be the former parking area that is located to the immediate west of the fenced Main Compound Area.

The following operations would be performed to refurbish the existing roads and the former parking area for use as a staging/dewatering area:

- The existing gravel roads (extending directly north from the northwestern corner of the fenced Main Compound Area towards the PCB Area) may require additional gravel or widening to assure that the equipment, planned for use during removal and treatment operations, can access the Main Ditch.
- The existing paved former parking area, located to the immediate west of the fenced Main Compound Area, would be used to stage the sediment, sort the sediment, dewater the sediment, set up and operate the chemical oxidation treatment system, and stage the treated sediment until it can be placed back on-site. It is assumed that this area, approximately 0.8 acres is size, is sufficient to handle these activities. If it is determined during the Remedial Design that this area is not of sufficient size, then the Remedial Design will include details on the expansion of this area. The former parking area would be surveyed by a licensed surveyor to determine the slope of that area such that a sump could be constructed to collect excess moisture that runs off of the sediment. The paved area would also be sealed with an asphalt sealant to prevent excess moisture from migrating down through any cracks in the pavement. This area would be designated as the dewatering pad and/or the staging area.
- The flow in the Main Ditch immediately upgradient of the PCB contamination area would be directed to a sump. The sump and earthwork required to direct water to the sump would be constructed using the excavation equipment discussed below. A submersible pump would be used to pump water from the sump to a location in the stream downgradient of the PCB contamination area. The water would be diverted past the planned area of excavation by pumping the water from upstream of the excavation area to an area immediately downstream of the excavation area using hoses. Piping would not be used because of the expected short-term duration of the project. This activity would be conducted sometime in the summer months when the flow in the Main Ditch would be minimal.

Sediment Excavation

A hydraulic crawler-mounted excavator (track-hoe) equipped with a two cubic yard bucket was selected. This selection was based on the evaluation and comparison of several types of excavation, removal, and dredging equipment including the vacuum truck, the vacuum dredge, the clamshell excavator, and the track-hoe. The track-hoe was found to be the most efficient and cost-effective means of removing the sediment at OU3.

The track-hoe is a widely used and economical piece of equipment used to remove large quantities of soil and sediment. This type of equipment can excavate sediment at the approximate rate of 130 cubic yards per hour. However, because the depth of excavation will be limited to one foot the excavation rate for this equipment was reduced for cost estimating purposes. The crawler-mounted hydraulic excavator track-hoe would be transported to WRF by truck. The excavator would excavate the top foot of sediment from the PCB areas of OU3. The sediment would be easily excavated from the ditch because the flow in the Main Ditch would have been previously diverted. The excavated sediment would be loaded into sealed gasketed rolloff containers mounted on the back of dump body trucks. The sealed gasketed containers would be used to assure that any excess moisture would not spill from the trucks while the sediment is transported to the staging/dewatering area. The sediment would be stockpiled at the staging/dewatering area for subsequent treatment using chemical oxidation.

Sediment suspension would be minimized during excavation because water in the drainage ditch would be diverted around the area of excavation. Sediment and erosion control systems would also be constructed to assure that suspended sediment does not get into the downstream portions of the Main Ditch. It is important to control sediment migration because it could impact ecosystems and nearby wetlands by depositing contaminants contained within the suspended sediment.

Volume of Sediment to be Excavated

The sediment samples collected from the PCBs area of OU3 contained PCB-1260 at levels that may adversely effect human health or the environment. The majority of the aquatic organisms in this ditch area burrow into the top two to four inches of the sediment. Analytical data indicates that the samples collected to a depth of six inches contain PCBs, PAHs, and pesticides. The removal of a one-foot layer of sediment from the PCBs area of OU3 would reduce the potential risks associated with the sediment. Samples would be collected at a depth of one-foot to assure that all of the PCBs that may adversely effect human health and the environment had been removed. The volume of sediment requiring removal and treatment from OU3 was estimated to be approximately 550 cubic yards. In order to ensure that the aquatic environments would not come in contact with any residual PCBs, a layer of clean sand would be placed over the excavation area prior to dismantling the ditch diversion pumping system.

Sediment Dewatering

The sediment removed from the Main Ditch of OU3 would be stockpiled on the paved dewatering pad (former parking area) such that the excess moisture could evaporate or run off. The excess water would be collected in a sump. An engineered sump would be constructed in the lower area of the former parking area. The water would evaporate and flow off of the sediment. A temporary berm could be put around the perimeter of the paved area to assure that all flow is diverted to the sump. The water that collects in the sump would be discharged to the Main Ditch once samples had been collected and analyzed to assure that the water did not contain any PCBs, PAHs, or pesticides in excess of the chronic ambient water quality criterion. If the water did contain these compounds in excess of the chronic ambient water quality criteria, then it would be properly disposed of off-site.

Background Information on Chemical Oxidation

Samples of the sediment from the area to be treated at OU3 would be tested during a treatability study. The treatability study would be designed to initially determine and refine the treatment system design requirements for the chemical oxidation system that will effectively degrade the

PCBs. Chemical oxidation involves the addition of a non-hazardous reagent (a proprietary compound designated as MP-5000) and water to the sediment requiring treatment. Oxygen is then added, in conjunction with a slight adjustment in pH (0.5 to 1.0) which facilitates the destruction of the Carbon-Oxygen bonds and other organic bonds. The end result of this modified oxidation reaction is basic elements and compounds that are non-hazardous.

The sediment, after being dewatered and screened, would be fed into a hopper where it would then be loaded onto the main conveyor belt. A feed conveyor, located directly above the main conveyor, would allow reagent to be applied to the sediment as it passed beneath on the main conveyor belt. The reagent would be allowed to act on that sediment for approximately 10 to 15 seconds before the sediment would be processed to the mixer. The reagent, sediment, and water would be thoroughly mixed to allow the reagent to disperse throughout the entire sediment mixture. Sediment would be then slowly pushed out of the mixer as new sediment would be discharged into the mixer from the main conveyor belt. The sediment, pushed out of the mixer, would then be stockpiled and allowed to sit for a period of 24 hours. After 24 hours, the sediment would be sampled to confirm that the concentrations of organics had been reduced to the remediation goal.

Limited information pertaining to treatment by chemical oxidation is currently available because it is a new and innovative treatment technology. A treatability study to evaluate the site specific effectiveness of this treatment alternative would be required during the design that may include the use of 1%, 2%, 3%, 5%, and 10% reagent concentrations.

The details pertaining to the specific composition of the reagent (MP-5000) is limited due to the proprietary nature. The Material Safety Data Sheets, however, indicate that the reagent contains non-hazardous compounds such as silica quartz, calcium oxide, calcium silicate, and titanium oxide. Chemical oxidation is an emerging technology that would be an innovative and possibly cost-effective means of remediating the sediment at OU3 of WRF.

Final Disposition

The treated sediment would be placed back on-site once the analytical data was obtained to confirm that the treated sediment did not contain levels of compounds that would present risks to human health and the environment.

Vegetation Restoration

This alternative would also include the planting of specific vegetative plants that would foster restoration of both benthic and aquatic communities naturally present in the Main Ditch. The Remedial Design will include input from a stream restoration specialist to assure that the appropriate types of vegetation are replanted in the Main Ditch area to foster the redevelopment of the natural ditch communities. The specific plants that may foster this reestablishment include crown vetch, white birch, white pine, and willow.

7.2.3.2 Long-term Monitoring and Institutional Controls

The purpose of including long-term monitoring and institutional controls to this alternative is to limit unauthorized groundwater use, soil disturbance, and site access; inform the public of site hazards; provide a database of site conditions; and evaluate changes over time. To assess the effectiveness of the remedy, long-term monitoring will consist of periodic sampling of groundwater, surface water, sediment, and biota. Future long-term monitoring will confirm the impact of surface water runoff with regards to levels of inorganic compounds detected in surface water. The data collected would be reviewed at least every five years, as required by the NCP.

7.2.3.3 Overall Protection of Human Health and the Environment

Implementation of this alternative would remove and treat sediment-containing PCBs from the shallow sediment of OU3, thus ultimately protecting human health and the environment. The excavation operations, although protective of human health and the environment in the long run, would impact the benthic, aquatic, and vegetative ecosystems of OU3 and the surrounding waters of WRF where the Main

Ditch discharges. The vegetative and aquatic communities would most likely take at least one year to re-establish themselves within the new creek sediment.

7.2.3.4 Compliance with Applicable, or Relevant and Appropriate Requirements

Section 5.0 of this document has identified the chemical-, location-, and action-specific ARARs for OU3. The remediation goal for OU3 sediments is 1.0 ppm PCB.

The surface water quality in the Main Ditch would be protected during excavation operations through a combination of flow diversion and the institution of sediment and erosion control measures in order to minimize the suspension of sediment fines within the water column of the downstream flow.

Water that collects in the sump as a result of dewatering activities would be sampled prior to being discharged to the Main Ditch to assure that the PCBs were below the chronic ambient water quality criteria. The sediment would also be sampled to assure that the levels of PCBs had been reduced to the remediation goals and that the sediment would not pose any additional risk to human health and the environment.

All excavation and treatment components implemented, as part of this alternative, would be conducted in compliance with action-specific and location-specific ARARs.

7.2.3.5 Long-term Effectiveness and Performance

The long-term effectiveness of this remedial alternative would be met because the sediment would be treated thereby, reducing the potential long-term risks posed to human health and/or the aquatic and terrestrial environments. The long-term management effort associated with this alternative would involve confirmatory sampling to assure that the sediment had been treated. In addition, long-term efforts would be required as a component of the vegetation restoration activities. This alternative would assure protection of human health and the environment long after the property had been transferred to the USFWS for use as a wildlife refuge because the sediment would have been removed and treated.

7.2.3.6 Reduction of Toxicity and Mobility Through Treatment

The toxicity, mobility, and volume of PCBs would be permanently reduced through active removal and treatment of the sediment using chemical oxidation. Confirmatory sampling would be conducted to assure that the levels of PCBs had been reduced.

7.2.3.7 Short-term Effectiveness

Treatment of sediment using chemical oxidation would pose a short-term risk to workers involved in the implementation and operation of this treatment alternative due to the increased potential for exposure to the sediment and the increased potential for risk due to injury. It is not anticipated that this remedial alternative would have an impact on the local community.

The removal components of this alternative would have a short-term impact on the benthic, aquatic, and terrestrial environments currently present in the Main Ditch. The removal of the sediment would destroy the existing communities and efforts would be required to restore these communities. This restoration process could take at least one year to re-establish itself.

7.2.3.8 Implementability

The implementation of this treatment alternative requires a treatability study to initially determine and refine the chemical oxidation/treatment system requirements. The implementation of a vegetation restoration project that would foster the re-development of the benthic, aquatic, and vegetative communities naturally present prior to the initiation of remedial activities is also fairly difficult to implement. It is estimated that it will take at least one year for the ditch communities to be restored.

7.2.3.9 Cost

The estimated costs for Alternative C are presented in Tables B-4 and B-5 in Appendix B. Capital costs are estimated to be $353,000. The annual O&M costs associated with this alternative are

estimated to be $13,215. Total present worth for this alternative based on a 30 year (5% discount rate) implementation period are estimated to be $556,148 (refer to Table B-12, Appendix B).

7.2.3.10 State Acceptance

State acceptance will be addressed in the Decision Document.

7.2.3.11 Community Acceptance

Community acceptance will be addressed in the Decision Document.

7.2.4 Alternative D: Excavation/Bioslurry Treatment/Placement of Treated Sediment On-Site/Long-term Monitoring/Institutional Controls

7.2.4.1 Description

The levels of PCBs detected in the sediment at OU3 could be reduced using a combination of anaerobic and aerobic bioslurry treatment. The sediment would be excavated and subsequently staged on the dewatering pad in the same manner as that described for Alternative C.

The sediment, following excavation and subsequent dewatering, would be loaded into the bioslurry reactors where it would be mixed with microorganisms, nutrients, and other additives in a slurry (the solids content could range from as little as 20 to 30 percent to as high as 40 to 50 percent). The differences between aerobic and anaerobic bioslurry treatment systems is briefly outlined, followed by an overview of the role that aerobic and anaerobic bioslurry treatment systems would have in the remediation of PCB-1260. Treatability studies would be required to further develop and refine the design parameters required for the anaerobic/aerobic bioslurry treatment system that would be used to remediate the sediment at OU3.

Aerobic Bioslurry

Aerobic bioslurry treatment systems are treatment systems that reduce biodegradable organic compounds in a controlled environment. Aerobic bioslurry treatment enhances the degradation of organic compounds using either indigenous or exotic microorganisms. Aerobic bioslurry treatment systems differ from other biological treatment technologies in that treatment occurs in a biologically controlled system, providing the operator with the capability of increasing the degradation rate of organic compounds. The degradation rate can be optimized by providing the microbial population with an optimum supply of organic compounds, cometabolites, electron acceptors, nutrients, and other additives.

The sediment would be completely mixed in a slurry (typically at 40% solids). Oxygen levels would be maintained in these controlled treatment systems through the diffusion of air or oxygen into the slurry (Zappi et al., 1993).

Anaerobic Bioslurry

Anaerobic bioslurry reactors are similar to aerobic bioslurry reactors in that organic compounds are degraded in a controlled environment. Anaerobic bioslurry treatment, however, is performed in the absence of oxygen. The microorganisms degrade organic compounds into methane, carbon dioxide, and water in an anaerobic environment. Environmental parameters such as pH, temperature, and nutrient levels are monitored and optimized in the batch treatment process to increase the biodegradation rate of organic contaminants. Anaerobic bioslurry reactors are sealed from the environment so as to prevent oxygen from entering the reactor, while allowing methane and carbon dioxide to vent to the outside atmosphere.

Bioremediation of PCBs

Bioremediation of PCBs using bioslurry treatment would be accomplished through a combination of anaerobic and aerobic bioslurry treatment. Anaerobic and/or aerobic bioslurries have been demonstrated to effectively degrade PAHs, simple aromatics, petroleum hydrocarbons, pentachlorophenol, and explosives. Bench- and field-scale bioslurry treatment studies have been conducted at Yorktown Virginia, Hastings Naval Ammunition Depot of Nebraska, and at Joliet Army Ammunition Plant in Illinois. Research has indicated that anaerobic and aerobic

bioslurries could be used conjunctively to effectively degrade PCBs, PAHs, and pesticides (Fredrickson, 1996; Gunnison, 1996; Harvey, 1996). Bioremediation of PCBs and pesticides is potentially more challenging then bioremediation of other compounds because these compounds, particularly the highly chlorinated compounds such as PCB-1260, chlordane, and DDD, are difficult to degrade. In addition, these compounds are hydrophobic; therefore, the bioremediation treatment system must overcome this. Successful bioremediation would require the use of a catalyst to initialize the reaction. A surfactant is also used to aid in the desorption of the contaminant from the sediment particle. The amount of time required for slurrying the mixture is dependent on the degradation rate of the compounds.

Research has indicated that the most effective bioslurry process design entails the use of anaerobic bioslurry treatment (to dehalogenate the pesticide and PCB) followed by aerobic bioslurry treatment (to break down the rings) (Gunnison, 1996). The amount of time required for both anaerobic bioslurry treatment and aerobic bioslurry treatment would be determined during a biotreatability study.

A biotreatability study would be conducted to evaluate the effectiveness of aerobic and anaerobic bioslurry treatment. The biotreatability study would be organized into three phases: 1). examination of the ability of indigenous and/or exotic microorganisms to degrade the PCBs; 2). evaluation of several different surfactants for improving solubilization of these compounds into the aqueous phase of reaction; and 3). determination of the optimal treatment conditions for both the pilot-scale and full-scale treatment systems. The biotreatability study would take approximately six months to complete and would also include an evaluation of the sediment type (sand, clay, or silt) and the organic content of the sediment to determine how these characteristics may affect bioslurry treatment.

The biotreatability study would entail the development of a small-scale study to evaluate the biodegradation rate of approximately 20 grams of the WRF sediment in a 500-mL shaker tube. Radio-labeled Carbon-14 would be used in this initial study. Once the parameters had been evaluated and proven effective, the biotreatability study would advance to the bench-scale study. The bench-scale study would incorporate the use of approximately 1300 grams of sediment in a 5-L glass reactor. The parameters required for optimal degradation would be further evaluated and refined until the optimum conditions were determined. A pilot-scale study, based on these parameters, would then be conducted. Large reactors (70 to 30,000 gallons) would be used during this study to confirm that the operational parameters would allow for the optimum biodegradation of the PCB, PAH, and pesticide compounds at a larger scale.

Biotreatability study costs are highly dependent on the number of radio-tracer studies that would be required to evaluate the degradation of the organic compounds, the number of replicates that would be required to generate meaningful statistics, and the heterogeneity of the sediment. Treatability studies conducted at other sites have cost approximately $300,000 to $400,000. Although the treatability study is a significant investment, it is a necessary component of the remedial design because the optimum parameters for successful bioremediation are identified. The biotreatability study allows for the testing, adjustment, and fine-tuning of several important parameters. These include the amount of time necessary for anaerobic and aerobic slurrying; the selection, use of, and concentration of nutrients and surfactants requirements; and the mixing requirements.

Once the treatability study is completed, the full-scale treatment system would be designed, constructed, and implemented. Field-scale treatment using anaerobic and aerobic bioslurry treatment could be conducted in reactors as large as 400,000 gallons. The reactors would be sealed from the environment and equipped with a nitrogen (or other inert gas) line and an oxygen line. The nitrogen or other inert gas would be used to create anaerobic conditions and then oxygen would be used to stimulate aerobic degradation. The gas and aeration supply, amount of mixing, and anaerobic/aerobic treatment time would all be controlled based on the optimum conditions determined during the treatability study. Treated sediment would then be removed from the reactors, sampled to assure that the PCB concentrations had been reduced to

within levels that are protective of human health and the environment, and deposited back on-site.

7.2.4.2 Long-term Monitoring and Institutional Controls

The purpose of including long-term monitoring and institutional controls to this alternative is to limit unauthorized groundwater use, soil disturbance, and site access; inform the public of site hazards; provide a database of site conditions; and evaluate changes over time. To assess the effectiveness of the remedy, long-term monitoring will consist of periodic sampling of groundwater, surface water, sediment, and biota. Future long-term monitoring will confirm the impact of surface water runoff with regards to levels of inorganic compounds detected in surface water. The data collected would be reviewed at least every five years, as required by the NCP.

7.2.4.3 Overall Protection of Human Health and the Environment

Implementation of this alternative would treat the shallow sediment containing PCBs to levels at or below the remediation goal. The excavation, treatment, and ultimate placement of the treated sediment on-site would protect human health and the environment over the long-term. However, the implementation of this alternative would have an impact on the benthic, aquatic, vegetative, and terrestrial environments over the short term. The sediment removal activities would destroy the ecological environment naturally present in the Main Ditch. It is estimated that it would take at least one year for the ditch communities to re-establish themselves within the new creek sediment.

In addition, the implementation of this alternative would have an impact on the workers involved in the remedial activities. It is anticipated that the implementation of this alternative will have no impact on the local community.

7.2.4.4 Compliance with Applicable or Relevant and Appropriate Requirements

Section 5.0 of this document has identified the chemical-, location-, and action-specific ARARs for OU3. The remediation goal for OU3 sediments is 1.0 ppm PCB.

The surface water quality in the Main Ditch would be protected during excavation operations through a combination of flow diversion and institution of sediment and erosion control measures in order to minimize the suspension of sediment fines within the water column of the downstream flow.

The water that collects in the sump as a result of dewatering activities would be sampled, prior to being discharged to the Main Ditch, to assure that contaminants are below the chronic ambient water quality criteria. The sediment would also be sampled to assure that the levels of PCBs have been reduced to the remediation goal levels.

All excavation and treatment components implemented as part of this alternative would be conducted in compliance with action-specific and location-specific ARARs.

7.2.4.5 Long-term Effectiveness and Permanence

The long-term effectiveness of this remedial alternative would be met because the sediment would be treated thereby reducing the potential long-term risks posed to human health and/or the aquatic and terrestrial environments. The long-term management effort associated with this alternative would involve confirmatory sampling to assure that the sediment had been treated. In addition, long-term efforts would be required as a component of the vegetation restoration activities. This alternative would assure protection of human health and the environment long after the property had been transferred to the USFWS for use as a wildlife refuge because the sediment would have been removed and treated.

7.2.4.6 Reduction of Toxicity and Mobility Through Treatment

The toxicity, mobility, and volume of PCBs would be permanently reduced through active removal and treatment of the sediment using anaerobic followed by aerobic bioslurry treatment. Confirmatory sampling would be conducted to assure that the levels of PCBs had been reduced.

7.2.4.7 Short-term Effectiveness

Treatment of sediment using a combination of anaerobic and aerobic bioslurry treatment would pose a short-term risk to workers involved in the implementation and operation of this treatment alternative due to the increased potential for exposure to the sediment and the increased potential for risk due to injury. It is not anticipated that this remedial alternative would have an impact on the local community.

The removal components of this alternative would have a short-term impact on the benthic, aquatic, and terrestrial environments currently present in the Main Ditch. The removal of the sediment would destroy the existing communities and efforts would be required to restore these communities. This restoration process is estimated to take at least one year for the communities to re-establish themselves.

7.2.4.8 Implementability

This treatment technology may be relatively difficult to implement. Bioremediation of PCBs is challenging because these compounds strongly adsorb to the sediment particles and surfactants must be used to aid in the desorption. In addition, special microorganisms must be used to degrade these compounds. Although this treatment technology has not been conducted extensively in the field, research has shown that this technology can be effective for the degradation of PCBs using microorganisms. A treatability study would be conducted to initially develop, further refine, and optimize the treatment system parameters. This treatment technology is an emerging technology for the remediation of these compounds.

The implementation of a vegetation restoration project that would foster the re-development of the benthic, aquatic, and vegetative communities naturally present prior to the initiation of remedial activities is also fairly difficult to implement.

7.2.4.9 Cost

The estimated costs for Alternative D are presented in Tables B-6 and B-7 in Appendix B. Capital costs are estimated to be $1,693,126. The annual O&M costs associated with this alternative are estimated to be $13,215. Total present worth costs for this alternative based on a 30 year (5% discount rate) implementation period are $1,896,274 (refer to Table B-12 in Appendix B).

7.2.4.10 State Acceptance

State acceptance will be addressed in the Decision Document.

7.2.4.11 Community Acceptance

Community acceptance will be addressed in the Decision Document.

7.2.5 Alternative E: Stream Construction and Restoration/Long-term Monitoring/Institutional Controls

7.2.5.1 Description

The alternative would involve relocating the portion of the ditch that is contaminated with PCBs in order to eliminate exposure to this compound by the aquatic communities at WRF, which would then minimize exposure to higher order receptors. The stream would be diverted just upstream from the area where PCBs were detected. Figure 7-2 presents the proposed location for the newly constructed ditch. A meandering stream would be constructed through the wetlands north of the present ditch and connected to the present ditch, just north of Charlie Road. Aquatic vegetation indigenous to the wetlands at WRF would be planted in the newly constructed stream. It is anticipated that a new benthic community would colonize the new stream within one year. The fill from the newly excavated stream would be placed over the old ditch segment, which would "entomb" the PCB-contaminated sediments. The excavation would be performed during the summer months as described in Alternative C.

An option was considered for this alternative which consisted of creating a wetland area that could be constructed in the upper reaches of the Main Drainage Ditch. This would be accomplished by widening the drainage ditch and allowing it to "flood". The area of the ditch where the PCBs are present would be covered with the sediment that was excavated in the upper reaches of the ditch. Once this

flooded area was created, a wetland habitat would begin to establish itself. It was anticipated that this alternative would be similar in cost as the stream re-construction alternative.

The proposed engineered ditch (to measure approximately 1600 feet in length, six feet in width, and three feet in depth) would be constructed using a hydraulic crawler-mounted excavator (track-hoe). The vegetation currently growing in the area where the new ditch is being proposed would be cleared prior to ditch construction. The soil excavated during the construction of this new ditch would be stockpiled on the sealed former parking area until the vegetation in the proposed ditch had begun to flourish such that the flow from the existing ditch could be diverted through the proposed ditch. It is important that the vegetation in the proposed ditch has a chance to establish such that sediment suspension and erosion could be minimized.

Once the flow in the existing ditch had been diverted through the proposed ditch, the soil that had been excavated during construction of the proposed ditch and stockpiled at the former parking area, would be placed over the surface of the existing ditch. Grass, plants, and trees would then be planted in this area. The sediment containing PCBs would be covered, thereby minimizing exposure to environmental and human receptors.

7.2.5.2 Long-term Monitoring and Institutional Controls

The purpose of including long-term monitoring and institutional controls to this alternative is to limit unauthorized groundwater use, soil disturbance, and site access; inform the public of site hazards; provide a database of site conditions; and evaluate changes over time. To assess the effectiveness of the remedy, long-term monitoring will consist of periodic sampling of groundwater, surface water, sediment, and biota. Future long-term monitoring will confirm the impact of surface water runoff with regards to levels of inorganic compounds detected in surface water. The data collected would be reviewed at least every five years, as required by the NCP.

7.2.5.3 Overall Protection of Human Health and the Environment

Implementation of this alternative would reduce the potential risk posed to human health and/or the environment by eliminating the exposure pathway. This alternative would essentially entomb the PCBs by covering them with a layer of soil excavated from the construction of the proposed drainage ditch. Therefore, this alternative is protective of human health and the environment.

7.2.5.4 Compliance with Applicable, or Relevant and Appropriate Requirements

Section 5.0 of this document has identified the ARARs that would apply to the remedial activities at OU3 of WRF. All of the remedial activities would be conducted in accordance with the ARARs.

7.2.5.5 Long-term Effectiveness

The sediment would be covered with a layer of soil, thus eliminating potential exposure pathways. The soil cover would be inspected annually and additional grass, trees, and/or plants would be planted to assure that the integrity of the soil cover would not broken so as to adversely effect human health or the environment. Therefore, this alternative is an effective long-term remedial alternative.

7.2.5.6 Reduction of Toxicity, Mobility, or Volume Through Treatment

The covering of the sediment in the PCB Area reduces the potential for human health or environmental exposure. The soil cover would minimize the mobility of these compounds by eliminating the flow and covering the sediment. Therefore, this alternative reduces the mobility of these compounds and eliminates the potential for exposure to these toxic compounds.

7.2.5.7 Short-term Effectiveness

The implementation of this alternative would impact the ecosystem of WRF in the short term. The construction of the proposed ditch, as well as diversion of the existing ditch flow and subsequent covering, would displace the benthic and aquatic communities and destroy the vegetative communities. However, grass, plants, and trees that would foster the redevelopment of these communities would be planted to promote the re-colonization of the new stream segment. The implementation of this alternative would address the protection of the community during all remedial activities, the protection of workers

during the remedial action, the minimization of environmental impacts, and the time required for the natural communities to re-establish.

7.2.5.8 Implementability

The stream construction and restoration alternative can be implemented with relative ease. The equipment and materials are readily available. The most difficult remedial component to implement involves the restoration of the vegetative, benthic, and aquatic communities in the newly constructed ditch.

7.2.5.9 Cost

The estimated costs for Alternative E are presented in Tables B-8 and B-9 in Appendix B. Capital costs are estimated to be $212,771 and annual O&M costs are estimated to be $16,963. Total present worth costs for this alternative, based on a 30 year (5% discount rate) implementation period, are $473,535 (refer to Table B-12 in Appendix B).

7.2.5.10 State Acceptance

State acceptance will be addressed in the Decision Document.

7.2.5.11 Community Acceptance

Community acceptance will be addressed in the Decision Document.

7.2.6 Alternative F: Excavation with Off-Site Disposal in a Landfill/Long-term Monitoring/ Institutional Controls

7.2.6.1 Description

Sediment samples collected from the Main Ditch at OU3 of WRF indicated that the sediment contains levels of PCB-1260 which could pose a potential risk to human heath and/or the aquatic and terrestrial environments. The sediment would be excavated from the PCBs area, once the flow had been diverted in the same manner as described for the sediment excavation activities presented in Alternative C. The excavated sediment would then be loaded into sealed gasketed roll-off containers that would be mounted on a dump body truck. The sediment would be transported to the sediment-dewatering pad where the material would be stockpiled for a short period of time, thus allowing excess water to evaporate and/or collect in the sump. The former parking area, west of the Main Compound, would require the modifications discussed in Alternative C.

The off-site disposal contractor would test the sediment to determine the moisture content. In the unlikely event that the sediment moisture content was determined to be greater than 60%, the sediment would require solidification. Cement kiln dust or fly ash, a good adsorbent of moisture, could be mixed into the stockpiled sediment using a backhoe equipped with a tube that would blow the cement kiln dust or fly ash into the sediment. Once the moisture content of the sediment/cement kiln dust or fly ash mixture is determined to be less then 60%, the sediment would be ready for loading and subsequent off-site disposal.

The sediment would be loaded into the trucks using a 1.5 cubic yard wheel loader. The excavated sediment would be tested to confirm that the sediment does not fail a TCLP test. The excavated sediment would be disposed of at a local landfill.

7.2.6.2 Long-term Monitoring and Institutional Controls

The purpose of including long-term monitoring and institutional controls to this alternative is to limit unauthorized groundwater use, soil disturbance, and site access; inform the public of site hazards; provide a database of site conditions; and evaluate changes over time. To assess the effectiveness of the remedy, long-term monitoring will consist of periodic sampling of groundwater, surface water, sediment, and biota. Future long-term monitoring will confirm the impact of surface water runoff with regards to levels of inorganic compounds detected in surface water. The data collected would be reviewed at least every five years, as required by the NCP.

7.2.6.3 Overall Protection of Human Health and the Environment

The potential risks to human health and the environment would be reduced because the sediment would be removed from the site and disposed of off-site. The material would be transported and disposed of in a permitted waste landfill in accordance with all applicable regulations and requirements to assure that the sediment does not pose potential future risk to human health and the environment.

7.2.6.4 Compliance with Applicable, or Relevant and Appropriate Requirements

The chemical-specific ARARs, including the clean-up goal of 1.0 ppm for PCB-1260 for sediment, will be met upon completion of this remedial alternative. The excavation, loading, transporting, and landfilling of the sediment will be conducted in accordance with all applicable regulations outlined in section 5.0.

7.2.6.5 Long-term Effectiveness

The sediment is removed from the site and disposed of off-site; therefore, this alternative is effective over the long-term. The off-site landfill currently meets the necessary requirements and regulations to assure protection of human health and the environment; however, there is no guarantee that the landfill would continue to be operated in a safe manner. There is always the potential for long-term liability associated with the ultimate disposal of the sediment in an off-site landfill.

7.2.6.6 Reduction of Toxicity, Mobility, or Volume Through Treatment

The toxicity and volume of PCBs would not be reduced through treatment, rather, the material would be transferred to another location. The mobility of the PCBs would be reduced if cement kiln dust or fly ash was mixed into the sediment before it was loaded into the trucks for off-site disposal.

7.2.6.7 Short-term Effectiveness

There are short-term risks to excavation workers, and to the local community from excavation and loading of the sediment. There are also short-term risks associated with transport and ultimate disposal of the excavated sediment.

7.2.6.8 Implementability

The excavation and ultimate disposal of the sediment at OU3 of WRF can be implemented with relative ease. The equipment and materials are readily available.

7.2.6.9 Cost

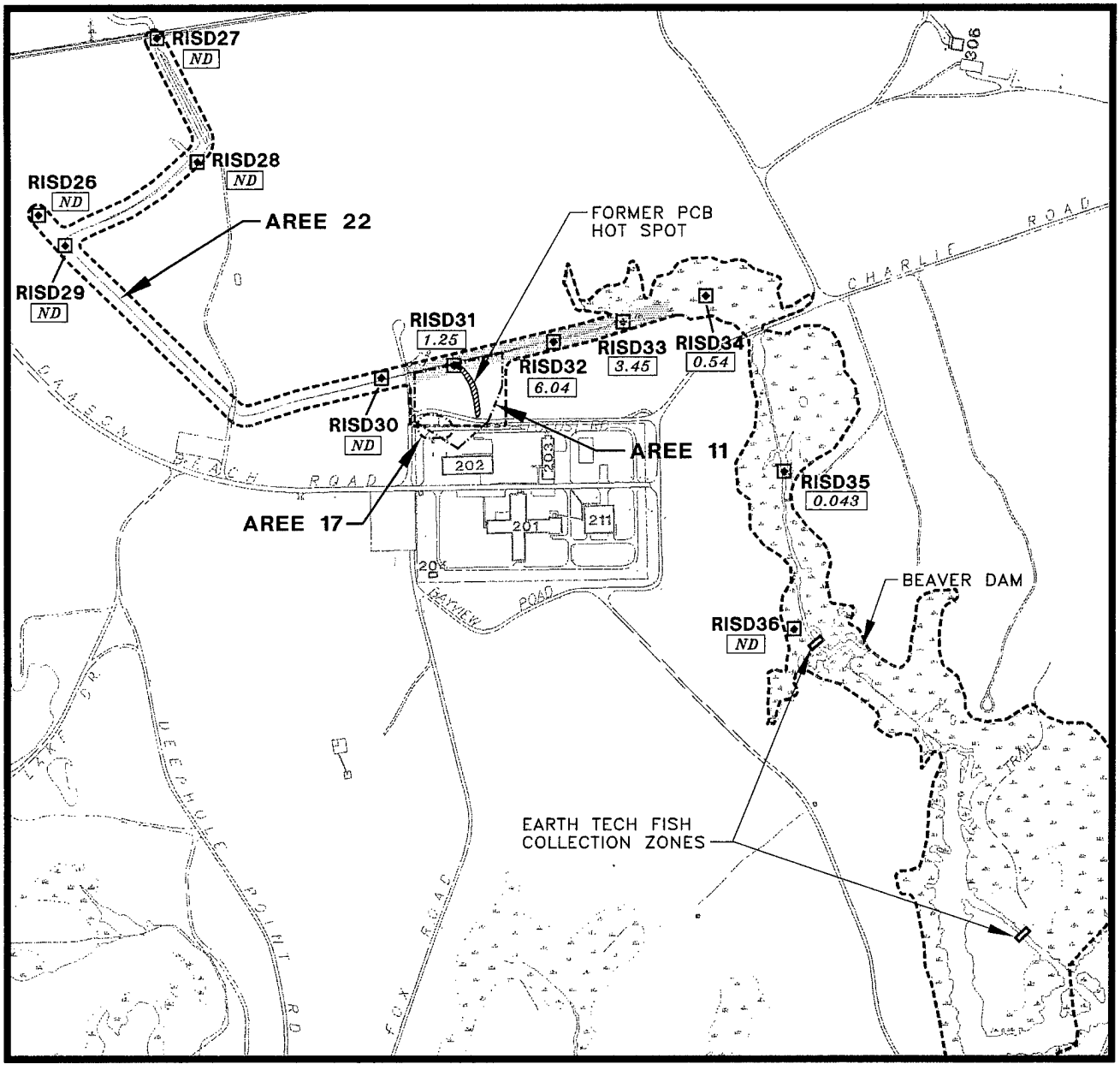
The estimated costs for Alternative F are presented in Tables B-10 and B-11 in Appendix B. Capital costs are estimated to be $204,589. The annual O&M costs associated with this alternative are estimated to be $13,215. Total present worth costs for this alternative based on a 30 year (5% discount rate) implementation period are $407,736 (refer to Table B-12 in Appendix B).

7.2.6.10 State Acceptance

State acceptance will be addressed in the Decision Document.

7.2.6.11 Community Acceptance

Community acceptance will be addressed in the Decision Document.



LEGEND:

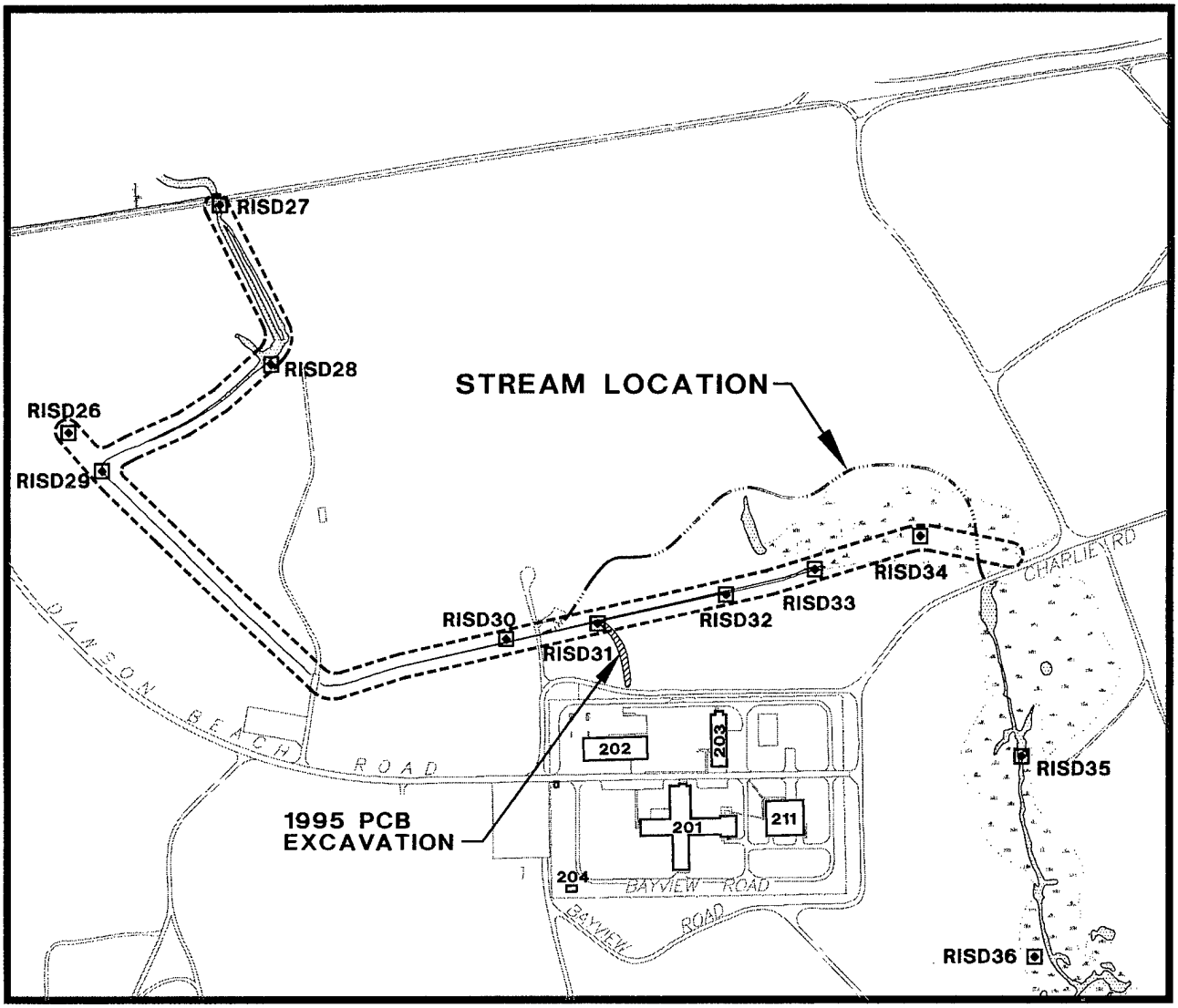
- RI SURFACE WATER/SEDIMENT SAMPLE LOCATION
- 3.45 CONCENTRATIONS OF PCBs (IN µg/g)
- ROAD
- FENCE
- WATER
- SWAMP
- LOCATION OF OU3
- MAIN PORTION OF DITCH FOR REMEDIAL ACTION

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0 600 1200
SCALE FEET

US ARMY ENVIRONMENTAL CENTER

CONTRACT NO. DACA31-94-D-0064	FIGURE 7-1
ICF KAISER 1301 Continental Drive Suite 101 Abingdon, Maryland 21009 (410) 612-6350	WOODBRIDGE RESEARCH FACILITY
PREPARED CST / TASK NO: 66220	PCB REMOVAL AREA FOR REMEDIAL ACTION AT OU3
CHECKED PT / ICF DWG NO: OU3-PCB	
DATE 08-19-97	



LEGEND:

- WATER
- SWAMP
- LOCATION OF OU3
- RI SURFACE WATER/SEDEMENT SAMPLE LOCATION
- PROPOSED STREAM RELOCATION

N

0 500 1000

SCALE FEET

US ARMY ENVIRONMENTAL CENTER

CONTRACT NO. DACA31-94-D-0064	FIGURE 7-2
ICF KAISER 1301 Continental Drive Suite 101 Abingdon, Maryland 21009 (410) 612-6350	WOODBRIDGE RESEARCH FACILITY
PREPARED CST / TASK NO: 66220	STREAM RELOCATION MAP
CHECKED PT / ICF DWG NO:	
DATE 10-01-97 / OU3-STR	

8.0 COMPARISON OF REMEDIAL ALTERNATIVES

The detailed evaluation presented in Section 7.0 discussed the extent to which each remedial alternative would meet the evaluation criteria. To aid in identifying and assessing relative strengths and weaknesses of the remedial alternatives, this section provides a comparative analysis of all of the alternatives. As previously discussed, the remedial alternatives are as follows:

- Alternative A: No Action;
- Alternative B: Natural Attenuation/Long-term Monitoring with Institutional Controls;
- Alternative C: Excavation/Ex-Situ Treatment Using Chemical Oxidation/On-Site Placement/ Long-term Monitoring/Institutional Controls;
- Alternative D: Excavation/Bioslurry Treatment/Placement of Treated Sediment On-Site/ Long-term Monitoring/Institutional Controls;
- Alternative E: Stream Construction and Restoration/Long-term Monitoring/Institutional Controls; and
- Alternative F: Excavation with Off-Site Disposal in a Landfill/Long-term Monitoring/ Institutional Controls.

These six alternatives are compared to highlight the differences between the alternatives and to identify trade-offs in meeting the criteria. Table 8-1 presents the major components of each of the six remedial alternatives.

8.1 OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

The U.S. Army plans to transfer the 579-acre WRF property to the USFWS for use as a wildlife refuge. No remedial actions are taken for the No Action alternative (Alternative A), and this alternative has been evaluated solely for the use as a baseline for comparison. This alternative offers no protection to human health or the environment.

Alternative B, Natural Attenuation/Long-term Monitoring with Institutional Controls would provide for educating the public to inform them about the risks identified earlier. Long-term monitoring would also be instituted to monitor the extent of natural attenuation and this information would be included as part of the public information database. Alternative B does not involve any active removal or treatment components; however, human health would be protected to the greatest extent practicable through both the implementation of a long-term monitoring program and the development and enforcement of institutional controls. This alternative would not include any measures to actively remove or treat the sediment; however, the existing ecosystem would not be destroyed during the process of removal and/or treatment activities. The Natural Attenuation/Long-term Monitoring with Institutional Controls alternative, unlike any of the four remaining (not including Alternative A) treatment and/or disposal alternatives evaluated, limits the activities which would disturb the sediment and release fine sediment particles into the surface water. In addition, the wetland areas would not be destroyed during site preparation, excavation, and/or treatment operations.

Alternative C, (Excavation/Ex-Situ Treatment Using Chemical Oxidation/On-Site Placement/Long-term Monitoring/Institiutional Controls) and Alternative D, (Excavation/Bioslurry Treatment/Placement of Treated Sediment On-Site/Long-term Monitoring/Institiutional Controls) would protect human health and the environment. These alternatives involve the treatment of the sediment using ex-situ treatment techniques that include either chemical oxidation or a combination of anaerobic and aerobic bioslurry treatment. Alternative C and Alternative D would require the excavation and removal of approximately 550 cubic yards of sediment using a hydraulic crawler-mounted excavator (track-hoe). The sediment would be stockpiled and subsequently treated. The treated sediment would be placed back on-site once confirmatory samples indicated that the PCBs (detected in the sediment) had been treated to within levels that would be protective of human health and the environment. Benthic communities would be further protected from residual concentrations of PCBs by placing the treated sediment back where it had been originally excavated. However, the excavation activities associated with Alternative C and Alternative D would affect the vegetative, benthic, and aquatic communities that

currently exist in the Main Ditch. These remedial alternatives, along with the other two active removal/treatment alternatives (Alternatives E and F) include plans for vegetation restoration. The appropriate vegetation must be planted to foster the redevelopment of indigenous communities. It is estimated that these communities would, however, begin to flourish within approximately one year.

Alternative E (Stream Construction and Restoration/Long-term Monitoring/Institutional Controls) would also protect human health and the environment because the proposed ditch would be constructed and the existing flow in the Main Ditch would be diverted through the new ditch. The soil excavated during construction of the new ditch would be used as a soil cover for the current drainage ditch, thus eliminating the potential exposure pathways. This alternative would essentially destroy the existing ecosystems in the location of both the new and the existing ditches. Vegetation restoration activities would be involved in restoring both areas.

Alternative F (Excavation with Off-Site Disposal in a Landfill/Long-term Monitoring/Instutional Conrols) would protect human health and the environment at WRF; however, the risks to human health and the environment would not be completely eliminated because the sediment would be transported off-site for disposal in an off-site landfill. It is anticipated, based on the current analytical results, that this sediment may be disposed of as a non-hazardous waste in an off-site landfill. The selection of off-site disposal in a landfill as the remedial alternative at OU3 bears a long-term liability because the Army does not have a guarantee that the landfill would continue to be operated in a manner that is fully protective of human health and the environment. The transportation of the sediment from the WRF facility to the landfill would also involve a short-term risk due to excavation and transportation activities.

The purpose of including long-term monitoring and institutional controls to alternatives C through F is to limit unauthorized groundwater use, soil disturbance, and site access; inform the public of site hazards; provide a database of site conditions; and evaluate changes over time. To assess the effectiveness of the remedy, long-term monitoring will consist of periodic sampling of groundwater, surface water, sediment, and biota. Future long-term monitoring will confirm the impact of surface water runoff with regards to levels of inorganic compounds detected in surface water. The data collected would be reviewed at least every five years, as required by the NCP.

8.2 COMPLIANCE WITH APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

Compliance with ARARs is a threshold criterion that must be met by the selected remedial action. Alternative A (No Action) would not meet this criterion.

The five remaining alternatives, Alternatives B (Natural Attenuation/Long-term Monitoring with Institutional Controls), Alternative C (Excavation/Ex-Situ Treatment Using Chemical Oxidation/On-Site Placement/Long-term Monitoring/Institutional Controls), Alternative D (Excavation/Bioslurry Treatment/Placement of Treated Sediment On-Site/Long-term Monitoring/Institutional Controls), Alternative E (Stream Construction/Restoration Long-term Monitoring/Institutional Controls), and Alternative F (Excavation with Disposal in an Off-Site Landfill/Long-term Monitoring/Institutional Controls) would be capable of meeting ARARs. The quality of nearby surface water would be protected by proper sediment and erosion control measures during clearance, site preparation, excavation, and treatment operations by utilizing techniques that would minimize the suspension of sediment fines.

All of the components of these five alternatives would be conducted in compliance with ARARs. Treatment using either chemical oxidation or a combination of anaerobic and aerobic bioslurry treatment, if properly implemented and performed within the established operating parameters, would treat the sediment to within levels that are protective of human health and the environment such that it could be placed back on-site. Disposal of the sediment in an off-site landfill (Alternative F) would be conducted within the appropriate regulations. Location-specific and action-specific ARARs would be adhered to for the five remaining alternatives.

8.3 LONG-TERM EFFECTIVENESS AND PERMANENCE

Alternative A (No Action) would not meet this criterion because the risk would not be reduced beyond current risks posed by the site. Measures would not be taken to control or reduce the level of PCBs; therefore, human health and the environment would continue to be potentially exposed to these compounds.

Alternative B (Natural Attenuation/Long-term Monitoring with Institutional Controls) does not require an active removal/treatment component; however, this alternative includes provisions for long-term monitoring, implementation of institutional controls, and development and implementation of a public education program and database. These measures would allow for the protection of human health to the greatest extent practicable, while allowing the PCBs to naturally attenuate. The primary advantage of this alternative over the remaining four alternatives is that it includes measures to protect human health and the environment without destroying the ecosystem that is naturally present at WRF. The periodic collection of samples would monitor the extent of natural attenuation and allow for a continued public update.

Alternative C (Excavation/Ex-Situ Treatment using Chemical Oxidation/On-Site Placement/Long-term Monitoring/Institutional Controls), Alternative D (Excavation/Bioslurry Treatment/Placement of treated Sediment On-Site/Long-term Monitoring/Institutional Controls), Alternative E (Stream Construction/Restoration/Long-term Monitoring/Institutional Controls), and Alternative F (Excavation/Off-Site Disposal in a Landfill/Long-term Monitoring/Institutional Controls) would all provide long-term effective and permanent protection by treating/removing the sediment or preventing exposure to the sediment at OU3. The ecological and human health receptor exposure pathways, defined in the risk assessments, would be eliminated using these alternatives.

Alternatives C, D, E, and F offer long-term protection to human health and the environment at OU3 although to a lesser extent for Alternative F. Excavation combined with either chemical oxidation or anaerobic and aerobic bioslurry treatment (Alternatives C and D) would provide the greatest degree of long-term effectiveness and permanence by removing the top layer of sediment, treating the sediment and putting it back on-site. The diversion of the existing ditch through the proposed ditch followed by subsequent soil cover (Alternative E) would eliminate the potential exposure pathways while entombing the PCBs in place. The excavation with off-site disposal of sediment from the PCB area (Alternative F) at OU3 would eliminate exposure pathways. The primary disadvantage of Alternatives C, D, E, and F is that the natural ecosystem that exists in this area would be destroyed. These four remedial alternatives would include measures to restore the specific vegetation that will foster the re-development of these communities. The natural vegetative, benthic, and aquatic communities are expected to recover within one year.

8.4 REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT

Alternative A (No Action) and Alternative B (Natural Attenuation/Long-term Monitoring with Institutional Controls) would not provide any immediate reduction in the toxicity, mobility, or volume of the PCBs because removal or treatment of the sediment would not be components of these alternatives. Chemical concentrations in the sediment may decrease over time due to natural attenuation.

Alternative A (No Action) and Alternative B (Natural Attenuation/Long-term Monitoring with Institutional Controls) would not include any activities that would disturb the wetland or sediment that could adversely affect the natural ecosystems within OU3; however, nothing would be done to reduce toxicity, mobility, or volume of contaminants. The excavation and ex-situ treatment/disposal methods proposed as part of Alternatives C and D would remove and treat the sediment containing PCBs, thereby reducing the toxicity, mobility, or volume detected in the sediment at OU3.

The stream construction and restoration alternative and the excavation with off-site disposal alternative do not involve active measure to reduce the toxicity, mobility, or volume of contaminants through treatment. However, the exposure pathways are eliminated; therefore, the toxicity and mobility of the PCB is indirectly reduced. These two alternatives do not include any measures to reduce the volume of these compounds.

8.5 SHORT-TERM EFFECTIVENESS

Short-term protection of the public, workers, or the environment would not be met by Alternative A (No Action) because the PCBs are not reduced and measures are not taken to eliminate the exposure pathways. Alternative B (Natural Attenuation/Long-term Monitoring with Institutional Controls) would not have any short-term impacts to the ecosystem because removal and treatment components would not be included as part of this alternative.

Alternatives C, D, E, and F would each provide for short-term protection of the public, workers, and the environment during implementation. The use of proper measures to prevent the suspension of sediment fines in the surface water during intrusive activities would be instituted to protect the aquatic ecosystems within OU3 at WRF and downstream areas. Proper and necessary personal protective equipment would be required for site workers during all remedial activities. Alternatives C, D, E, and F would also effect the aquatic communities because vegetation would be disturbed and/or removed during site preparation, excavation, and treatment operations.

The excavation operations proposed as part of Alternatives C, D, E, and F require that the sediment be disturbed. This is likely to result in the mixing and suspension of fine-grained particles throughout the water column; therefore, all appropriate sediment and erosion control measures will be utilized to assure protection to the environment.

The length of time which would be required to implement the remediation alternatives follow in increasing order: Alternative A, Alternative B, Alternative F, Alternative E, Alternative C, and Alternative D. Alternative A would require no time to implement because no actions are taken. Alternative B and Alternative F would require approximately four months to implement. Alternative E is estimated to require 6 months to implement depending on the time required for vegetative growth. Alternative C and Alternative D would require approximately 18 months and 24 months to implement, respectively. The treatment time required as part of Alternatives C and D will be dependent on the results of the treatability studies that will refine treatment parameters.

8.6 IMPLEMENTABILITY

Alternative A (No Action) would be the easiest to implement as no changes would have to be made.

Alternative B (Natural Attenuation/Long-term Monitoring with Institutional Controls) would be fairly easy to implement. Alternative B would require no change in existing conditions and all components of Alternative B are readily available and would be implemented with relative ease. Administrative implementation of Alternative B would require coordination between the U.S. Army, the USFWS, the State of Virginia, and the USEPA to ensure continuity of the long-term management and monitoring of the site.

The equipment and materials required for excavation (components of the remaining four alternatives) are readily available. The equipment, materials, and treatment requirements associated with chemical oxidation and a combination of anaerobic and aerobic bioslurry treatment of the sediment are not readily available because treatability studies and engineering design are integral components of these remedial alternatives. Both chemical oxidation treatment and the combined usage of anaerobic and aerobic bioslurry treatment have not been utilized extensively for the treatment of PCBs. Extensive evaluation and design would be required prior to implementation. Site-specific treatability studies would be required and necessary to evaluate the potential applicability and performance of the treatment technologies (Alternatives C and D).

The implementation of Alternatives E and F would be conducted with relative ease compared to the implementation concerns associated with Alternatives C and D. The materials and equipment necessary for the excavation and disposal of the sediment at OU3 can be obtained with relative ease as they are commercially available.

8.7 COST

Table 8-2 provides a comparison of the costs of the six alternatives that are under consideration. Total capital, annual O&M costs, and present worth (discount rates of 5% over a thirty year period) for each remedial alternative that has been evaluated as part of this feasibility study are presented. The progression of total present worth from the least expensive to the most expensive alternative is: Alternative A, Alternative B, Alternative F, Alternative E, Alternative C, and Alternative D. Alternative F is the least expensive of the active treatment or removal/construction alternatives because it requires the least specialized equipment, materials, and engineering formulation and design. Alternative D is the most costly because of the extensive treatability study, design, and implementation concerns associated with bioremediation. Long-term liability will be associated with the selection of Alternative F because the

sediment is landfilled off-site. Alternative C is less expensive than Alternative D on a per cubic yard basis.

8.8 STATE ACCEPTANCE

State acceptance will be addressed in the Decision Document.

8.9 COMMUNITY ACCEPTANCE

Community acceptance will be addressed in the Decision Document.

8.10 SUMMARY OF DETAILED EVALUATION

Tables 8-1, 8-2, and 8-3 provide an overview of the findings of the detailed analysis. The information presented in this report can be used to aid in the selection of the most appropriate remedial technology for use at OU3 of WRF.

Table 8-1
Summary of Remedial Alternatives for Sediment at OU3

Alternative A - No Action
Alternative B - Natural Attenuation/Long Term Monitoring/Institutional Controls • Development of a Public Education Program and a Database Program of Pertinent Information • Institutional Controls • Long-term Environmental Monitoring Program • Long-term Management
Alternative C - Excavation/Ex-Situ Treatment Using Chemical Oxidation/On-Site Placement/Long-term Monitoring/Institutional Controls • Treatability Study • Excavation Using a Hydraulic Crawler-Mounted Excavator (Track-hoe) • Sediment Dewatering and Sorting • Chemical Oxidation Treatment • On-Site Placement of Treated Sediment • Vegetation Restoration • Institutional Controls • Long-term Environmental Monitoring Program • Long-term Management
Alternative D - Excavation/Bioslurry Treatment/Placement of Treated Sediment On-Site/Long-term Monitoring/Institutional Controls • Treatability Study • Excavation Using a Hydraulic Crawler-Mounted Excavator (Track-hoe) • Treatment Using Anaerobic Bioslurry Treatment Followed by Aerobic Bioslurry Treatment • On-Site Placement of Treatment Sediment • Vegetation Restoration • Institutional Controls • Long-term Environmental Monitoring Program • Long-term Management
Alternative E - Stream Construction and Restoration/Long-term Monitoring/Institutional Controls • Ditch Construction in An Area to the North of Existing Main Ditch • Diversion of Flow in Main Ditch to Man-Made Ditch • Placement of Excavated Soil from Construction of New Ditch on Top of Existing Main Ditch • Vegetation Restoration • Institutional Controls • Long-term Environmental Monitoring Program • Long-term Management
Alternative F - Excavation with Off-Site Disposal in a Landfill/Long-term Monitoring/Institutional Controls • Excavation Using a Hydraulic Crawler Mounted Excavator (Track-hoe) • Sediment Dewatering • Sediment Loading and Transport • Sediment Disposal • Vegetation Restoration • Institutional Controls • Long-term Environmental Monitoring Program • Long-term Management

Table 8-2

Summary of Capital, Annual O&M, and Present Worth Costs for OU3

Remedial Action (RA) Alternative	Capital Cost Estimate ($)	O&M Cost Estimate ($)	Present Worth Estimate[1] ($)
A. No Action	0	7,200	109,795
B. Natural Attenuation/Long-term Monitoring with Institutional Controls	33,861	17,865	308,491
C.Excavation/Ex-Situ Treatment using Chemical Oxidation/On-Site Placement/Long-term Monitoring/Institutional Controls	353,000	13,215	556,148
D. Excavation/Bioslurry Treatment/Placement of Treated Sediment On-Site/ Long-term Monitoring/Institutional Controls	1,693,126	13,215	1,896,274
E. Stream Construction and Restoration/Long-term Monitoring/Institutional Controls	212,771	16,963	473,535
F. Excavation with Off-site Disposal in a Landfill /Long-term Monitoring/Institutional Controls	204,589	13,215	407,736

[1] Present worth assumes a 30-year lifetime and 5% interest (discount) rate for federal money.

TABLE 8-3
Summary of Individual Analysis of Remedial Action Alternatives

Alternative		Protects Human Health and Environment?	Complies with ARARs?	Effective/ Permanent for Long-Term?	Reduces Toxicity, Mobility, or Volume through Treatment?	Effective Short-Term?	Implementable?	Accepted by Regulatory Agencies?	Accepted by Community?
A	No Action	No	No	No	No	No	Not Applicable	Not Available	Not Available
B	Natural Attenuation/ Long-term Monitoring With Institutional Controls	Yes	Yes	Yes	No	Yes	Yes	Not Available	Not Available
C	Excavation/ Ex-Situ Treatment Using Chemical Oxidation/ On-Site Placement/Long-term Monitoring/Institutional Controls	Yes	Yes	Yes	Yes	Yes	Yes	Not Available	Not Available
D	Excavation/Bioslurry Treatment/Placement of Treated Sediment On-Site/Long-term Monitoring/Institutional Controls	Yes	Yes	Yes	Yes	Yes	Yes	Not Available	Not Available
E	Stream Construction and Restoration/Long-term Monitoring/Institutional Controls	Yes	Yes	Yes	Yes	Yes	Yes	Not Available	Not Available
F	Excavation with Off-Site Disposal in a Landfill/Long-term Monitoring/Institutional Controls	Yes	Yes	Yes	Yes	Yes	Yes	Not Available	Not Available

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APPENDIX A

ADDITIONAL ECOLOGICAL RISK ASSESSMENT INFORMATION

APPENDIX A.1

COMPARISON OF CHEMICALS NOT IDENTIFIED AS COPC TO AVAILABLE TOXICITY VALUES

TABLE A.1-1

COMPARISON OF MAXIMUM CONCENTRATIONS TO SEDIMENT TRVs FOR CHEMICALS NOT IDENTIFIED AS COPCs IN OU3 SEDIMENTS

Units = mg/Kg

Chemical	Maximum Sediment Concentration	ER-L[A]	ER-M[A]	Other Guidelines	Environmental Effects Quotient (EEQ)		
					Ratio of Maximum Sediment Concentrations to ER-L	Ratio of Maximum Sediment Concentrations to ER-M	Ratio of Maximum Sediment Concentrations to Other Guidelines
Inorganics:							
Aluminum	15,900	---	---	---	---	---	---
Beryllium	2.44	---	---	---	---	---	---
Calcium	2,410	---	---	---	---	---	---
Chromium	23.0	81	370	---	0.3	0.1	---
Cobalt	36.1	---	---	---	---	---	---
Copper	25.9	34	270	---	0.8	0.1	---
Iron	34,600	---	---	20,000 [B]	---	---	1.7
Magnesium	1,830	---	---	---	---	---	---
Manganese	564	---	---	---	---	---	---
Nickel	19.1	20.9	51.6	---	0.9	0.4	---
Potassium	1,040	---	---	---	---	---	---
Sodium	1,240	---	---	---	---	---	---
Vanadium	68.8	---	---	---	---	---	---
Zinc	257	150	410	---	1.7	0.6	---

ER-L = Effects Range - Low. Concentration of chemical in sediment at which there is the potential for adverse affects to sensitive benthic organism life stages and/or species.
ER-M = Effects Range - Median. Concentration of chemical in sediment at which there is the potential for adverse effects to most benthic organisms.
--- = Value not available.

A All ER-L's and ER-M's from Long et al. (1995) unless otherwise noted.

B Lowest Effect Level (LEL) from OMEE (1993).

TABLE A.1-2

COMPARISON OF CONCENTRATIONS TO SURFACE WATER TRVs FOR CHEMICALS NOT IDENTIFIED AS COPCs IN OU3 SURFACE WATER

Units = ug/L

Chemical	Arithmetic Mean Surface Water Concentration	Surface Water TRVs		Environmental Effects Quotient (EEQ) Ratio of Arithmetic Mean Surface Water Concentrations to TRVs	
		Chronic	Acute	Chronic	Acute
Inorganics:					
Calcium	6,640	---	---	---	---
Iron	11,400	1,000 [A]	--- [B]	**11.4**	---
Magnesium	2,660	---	---	<0.1	<0.1
Manganese	369	80.3 [C]	1,470 [C]	**4.6**	0.3
Potassium	3,800	---	---	---	---
Sodium	2,340	---	---	---	---

A US EPA Ambient Water Quality Criteria (1992,1996). Hardness value of 50.0 mg/L was used in hardness-dependent equations because the detected value of 31.2 mg/L was too low to be used in the regression equation.

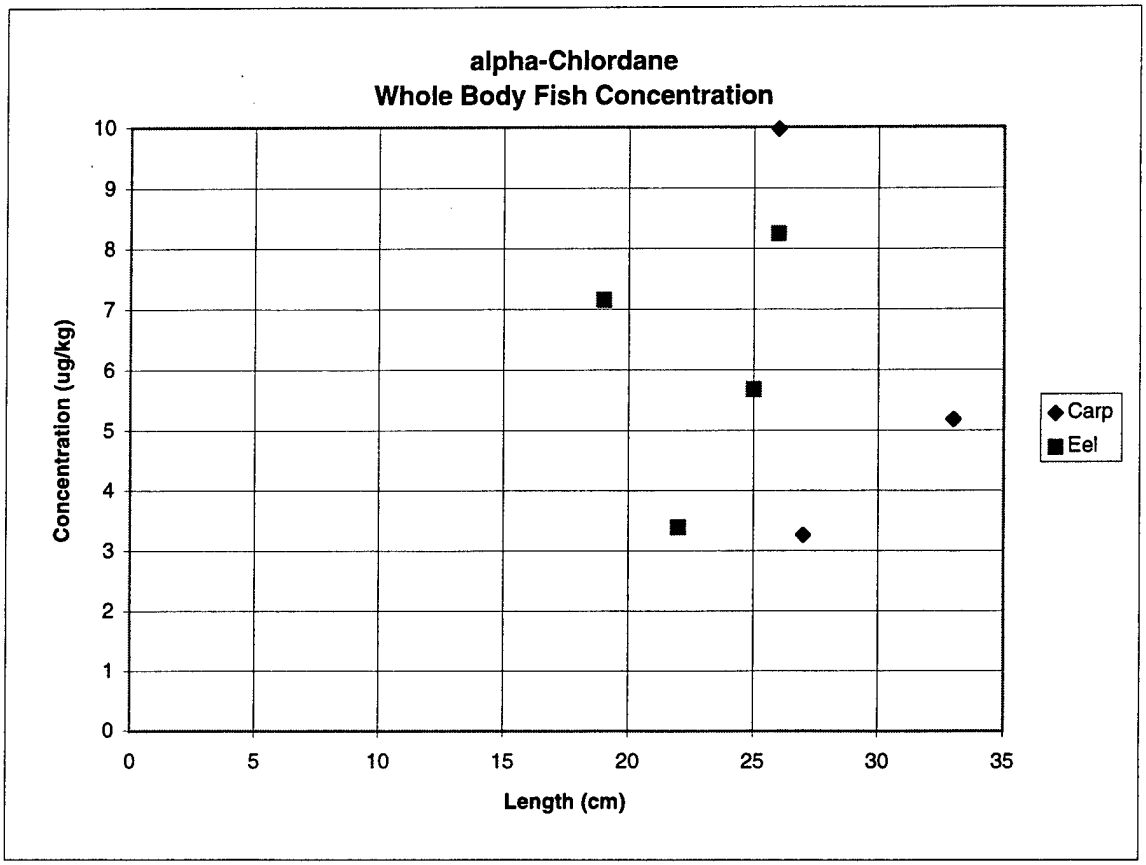
B An acute TRV was not available.

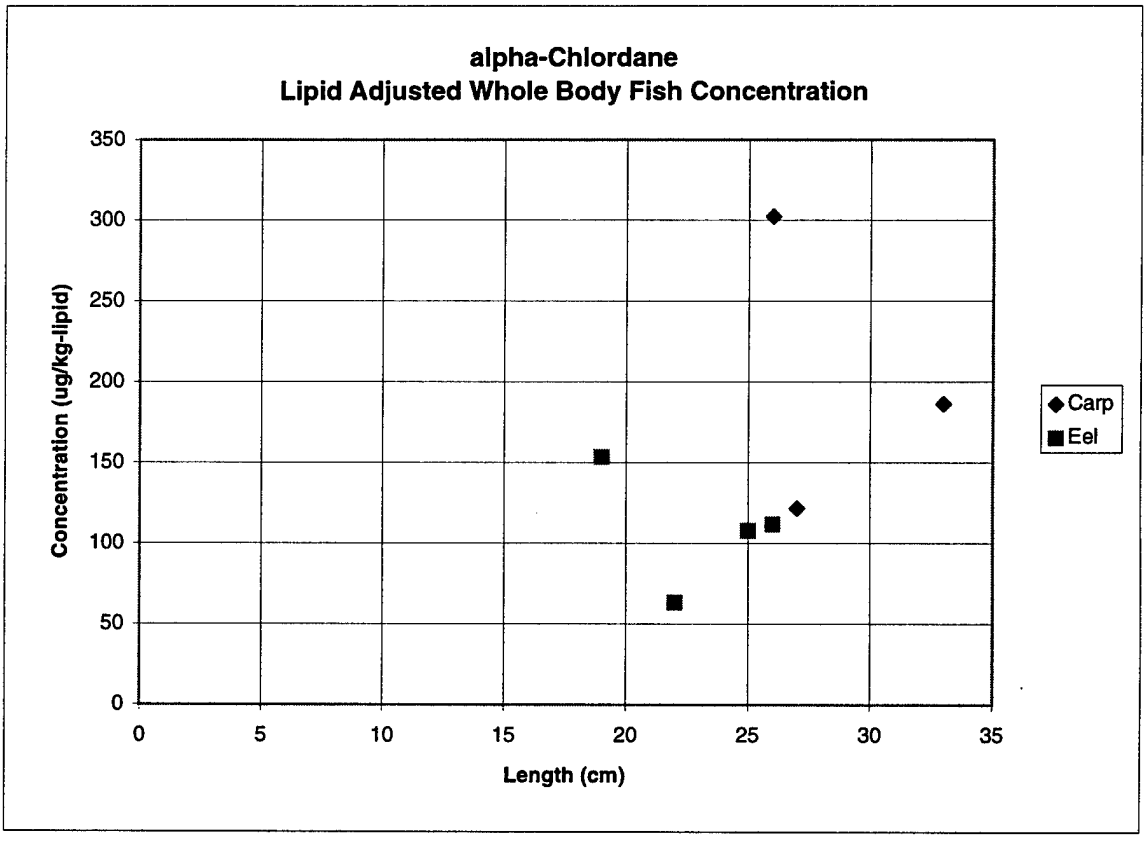
C Value from Suter and Mabrey (1994).

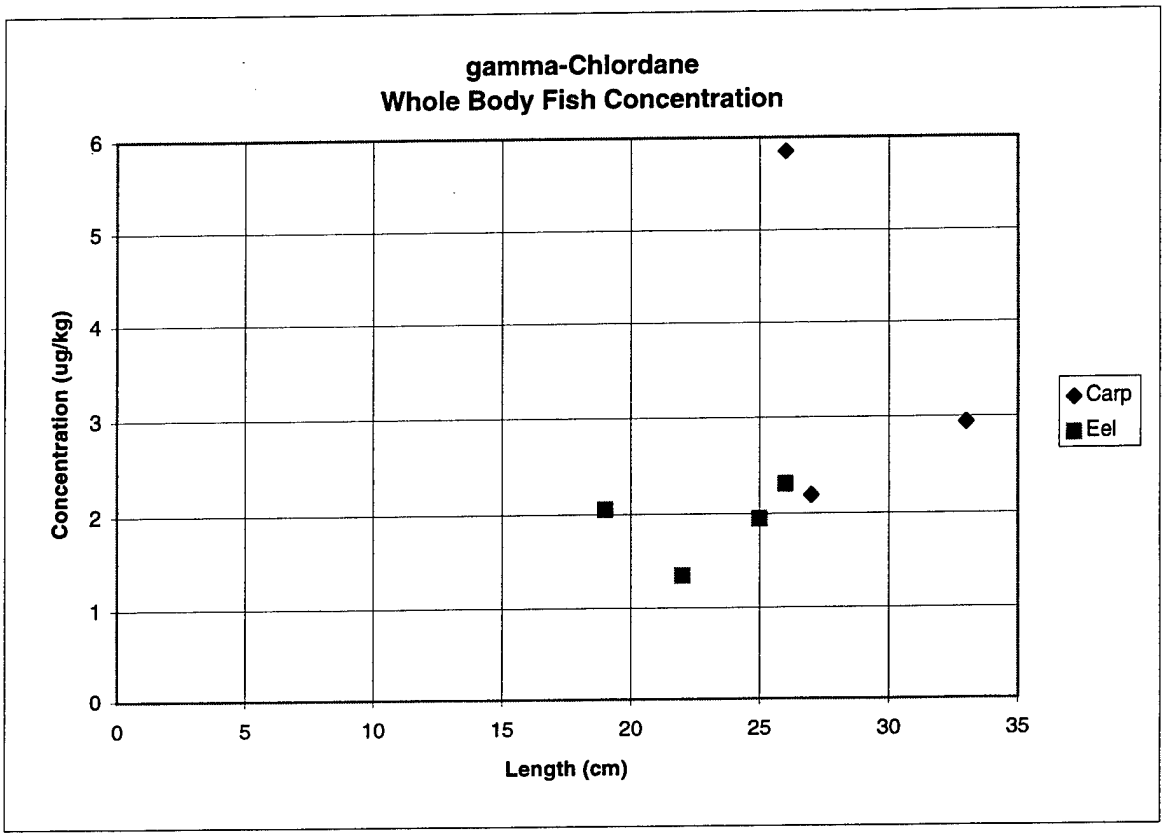
--- = Value not available.

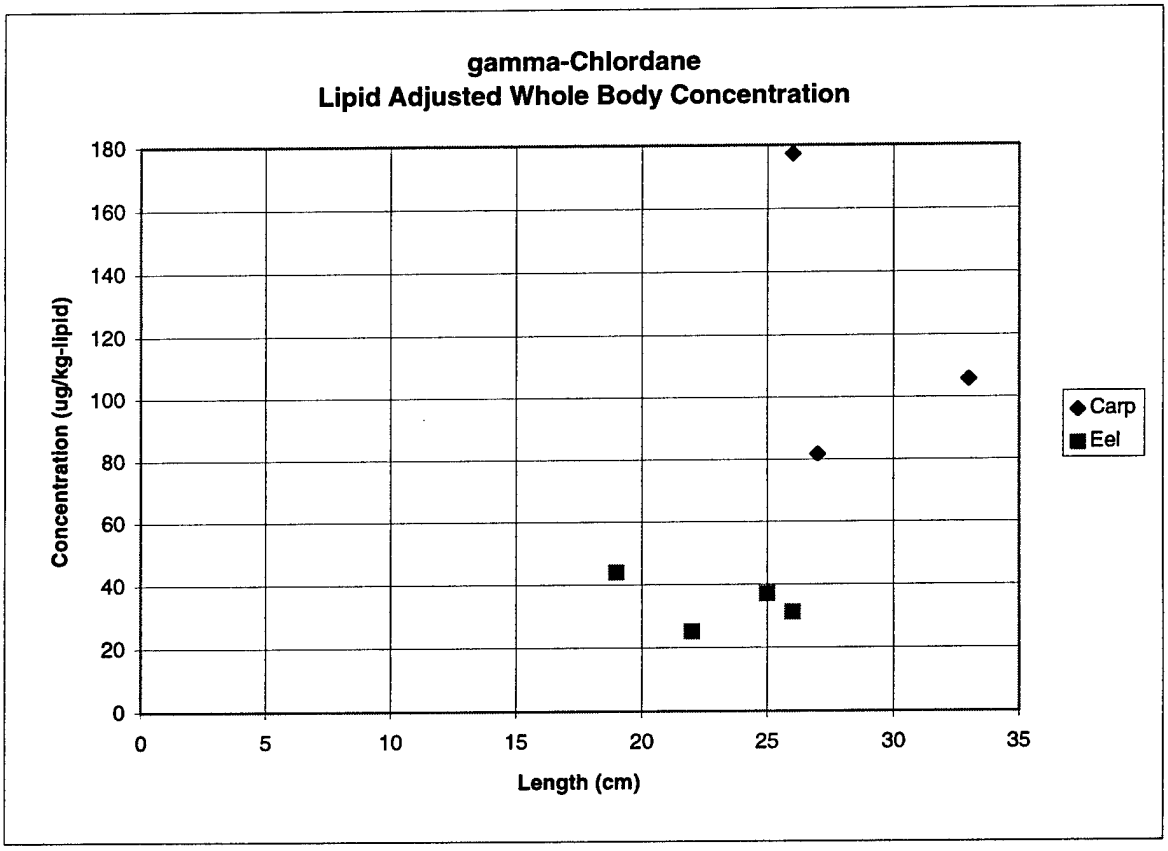
APPENDIX A.2

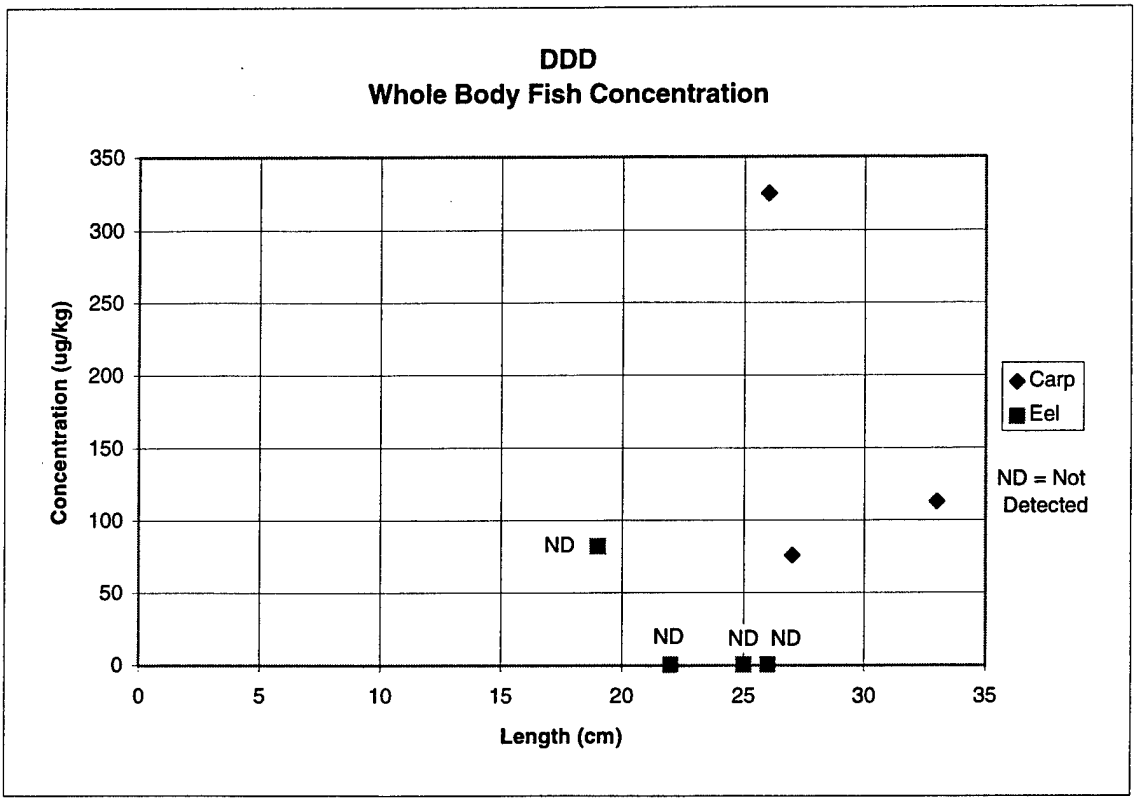
CHEMICAL CONCENTRATIONS DETECTED IN WHOLE BODY FISH TISSUE COMPARED TO FISH LENGTH

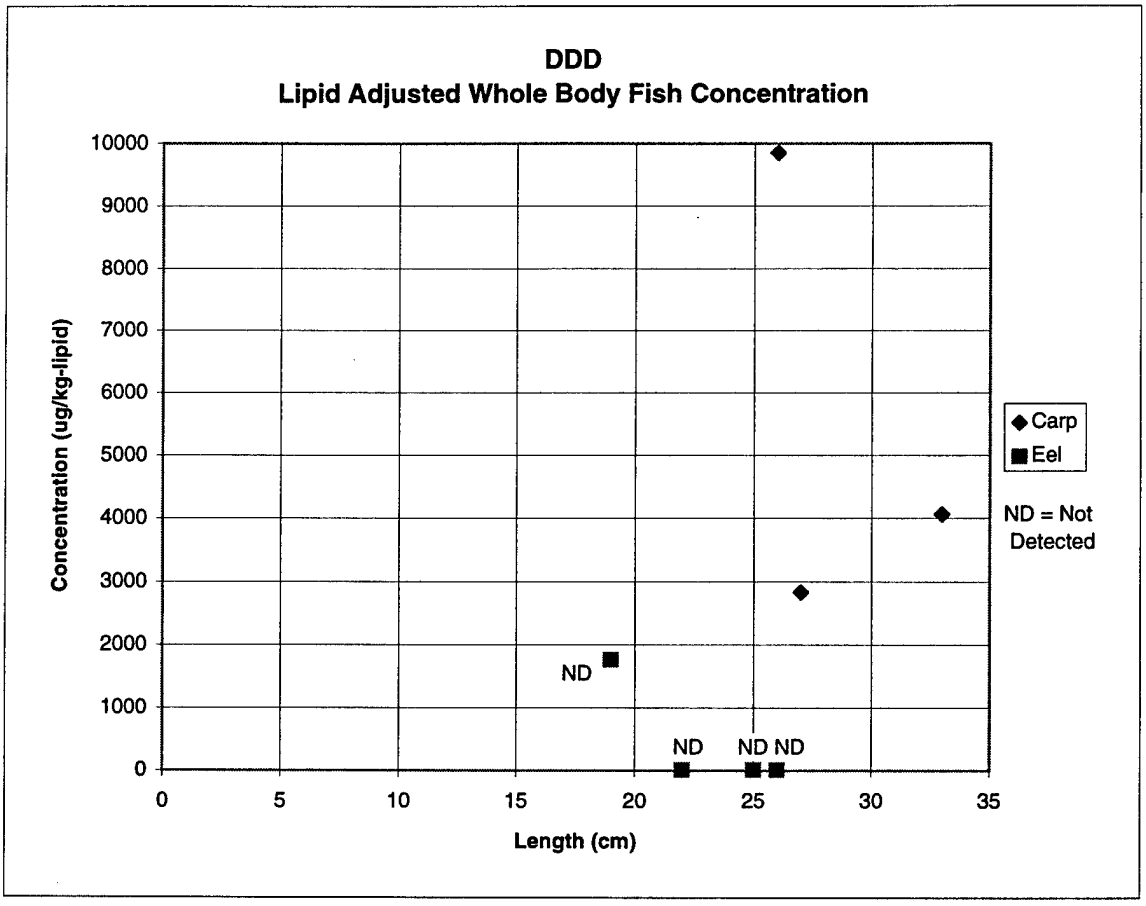

alpha-Chlordane
Whole Body Fish Concentration
Concentration (ug/kg)
0
1
2
3
4
5
6
7
8
9
10
0
5
10
15
20
25
30
35
Length (cm)
Carp
Eel

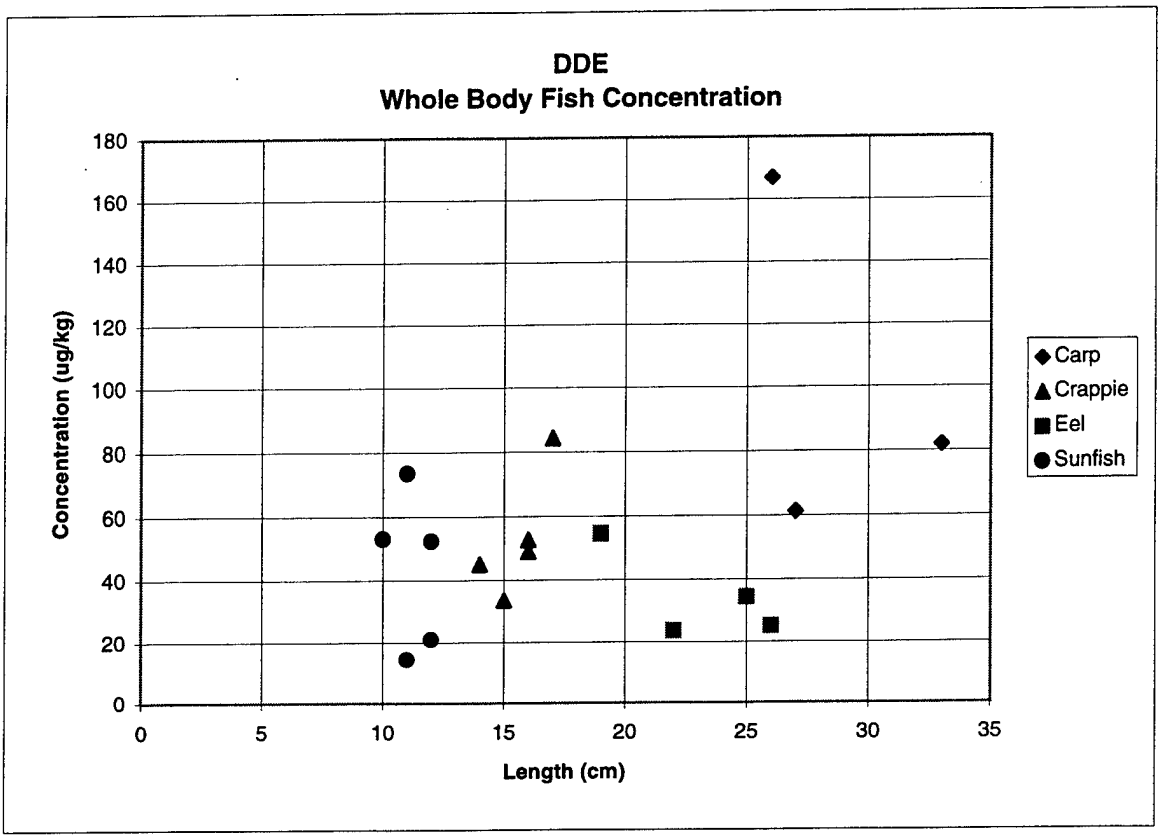

alpha-Chlordane
Lipid Adjusted Whole Body Fish Concentration
Concentration (ug/kg-lipid)
0
50
100
150
200
250
300
350
0
5
10
15
20
25
30
35
Length (cm)
Carp
Eel

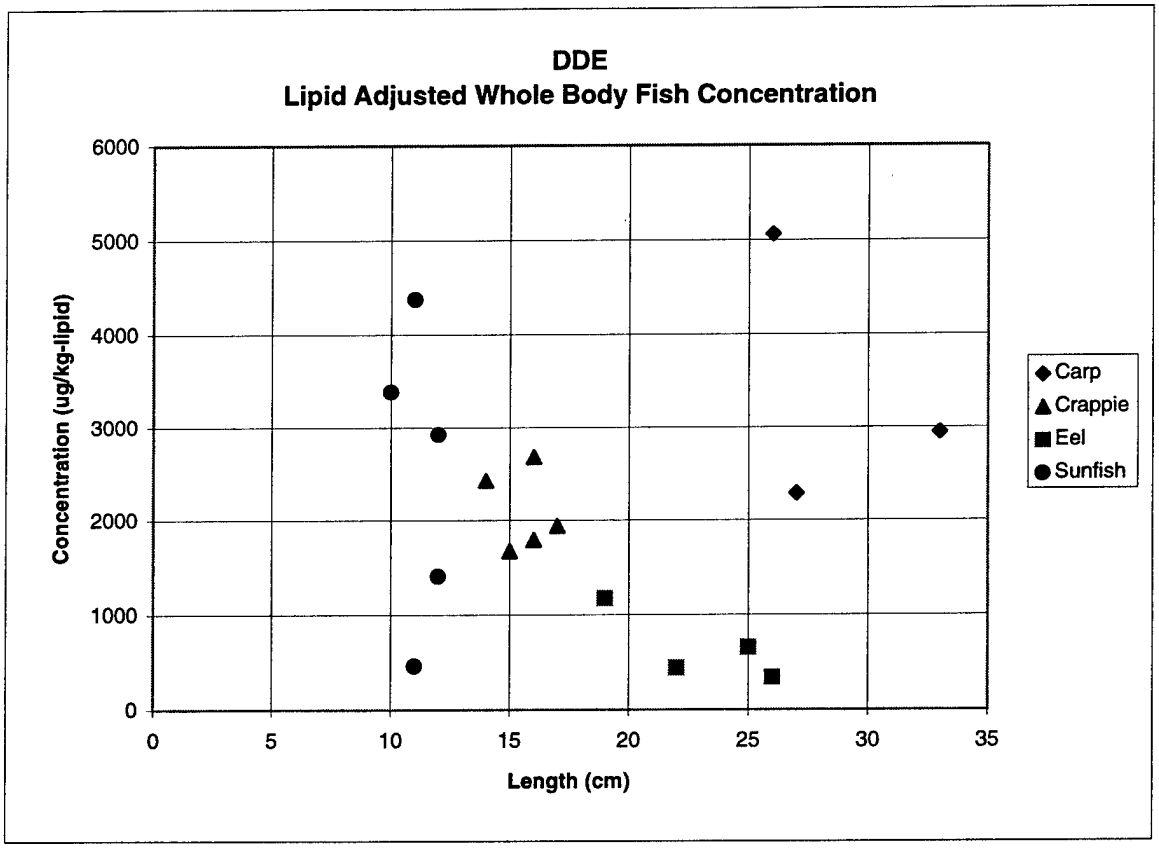

gamma-Chlordane
Whole Body Fish Concentration
Concentration (ug/kg)
0
1
2
3
4
5
6
0
5
10
15
20
25
30
35
Length (cm)
Carp
Eel

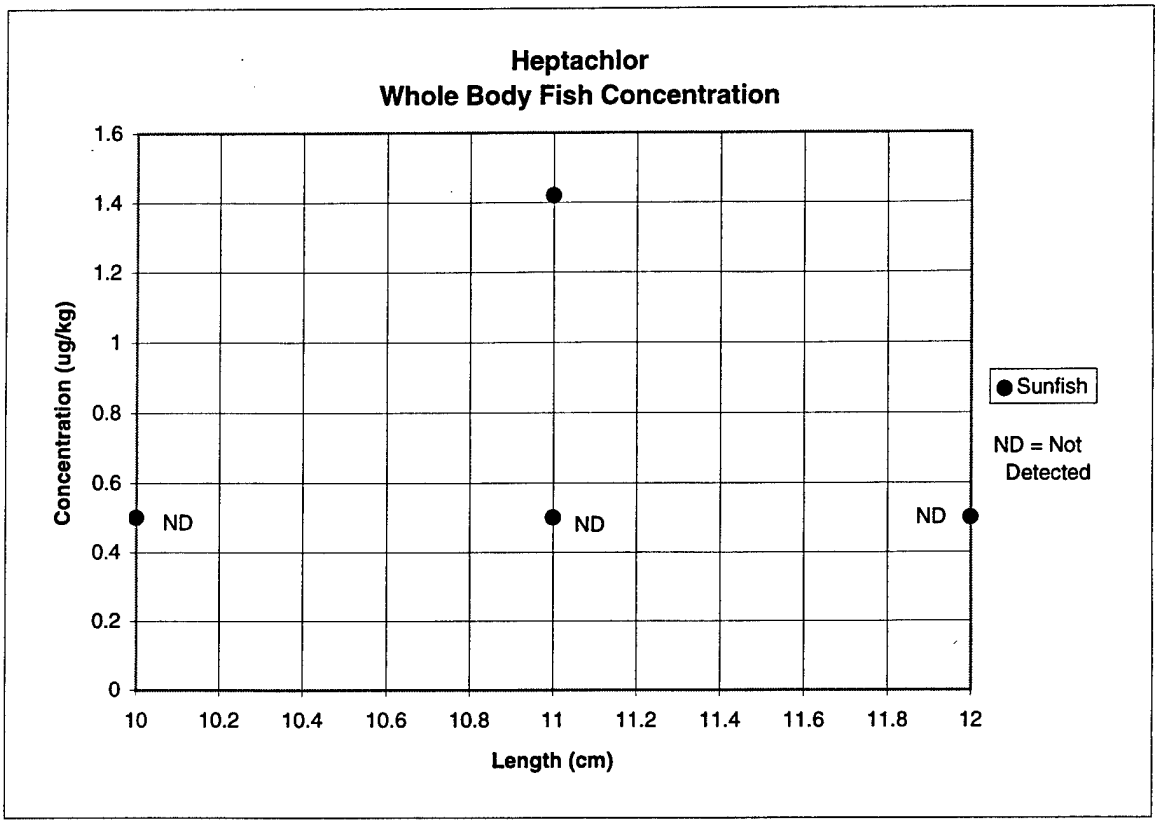

gamma-Chlordane
Lipid Adjusted Whole Body Concentration
Concentration (ug/kg-lipid)
0
20
40
60
80
100
120
140
160
180
0
5
10
15
20
25
30
35
Length (cm)
Carp
Eel

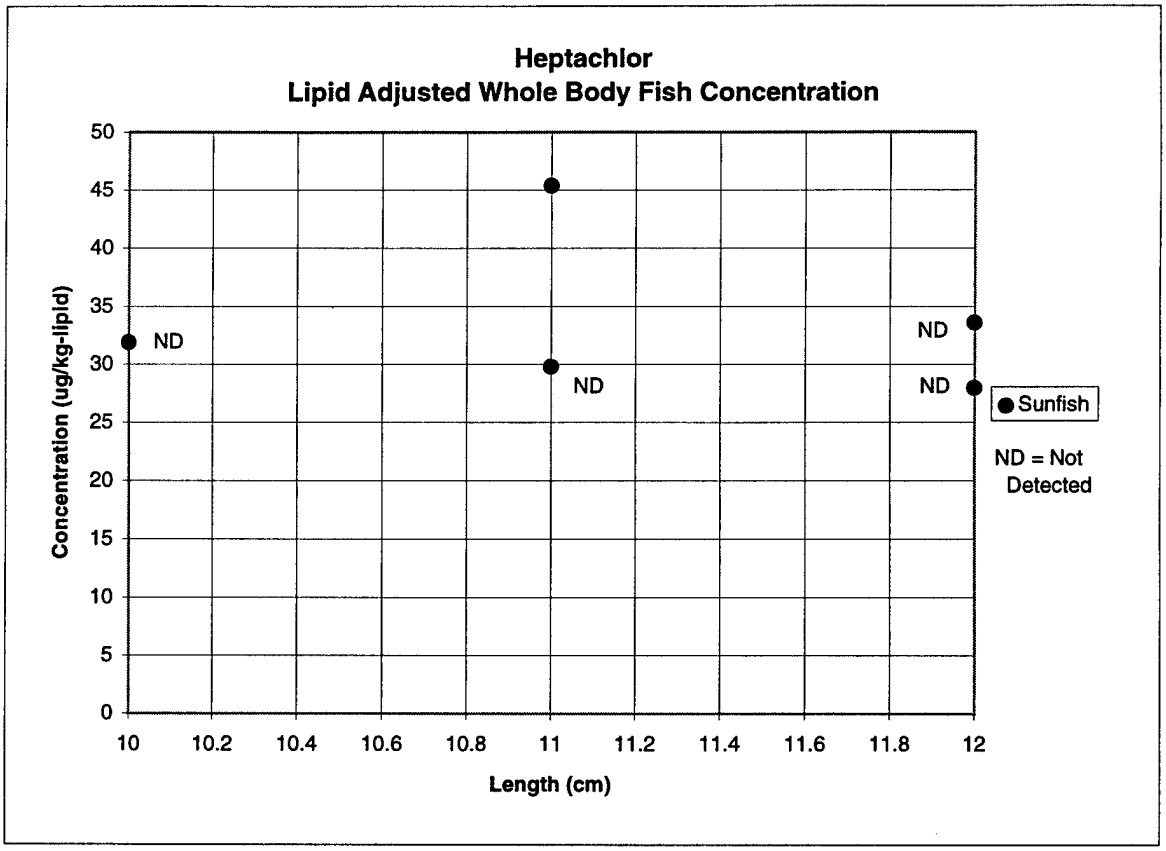

DDD
Whole Body Fish Concentration
Concentration (ug/kg)
350
300
250
200
150
100
50
0
0
5
10
15
20
25
30
35
Length (cm)
ND
ND
ND
ND
Carp
Eel
ND = Not Detected

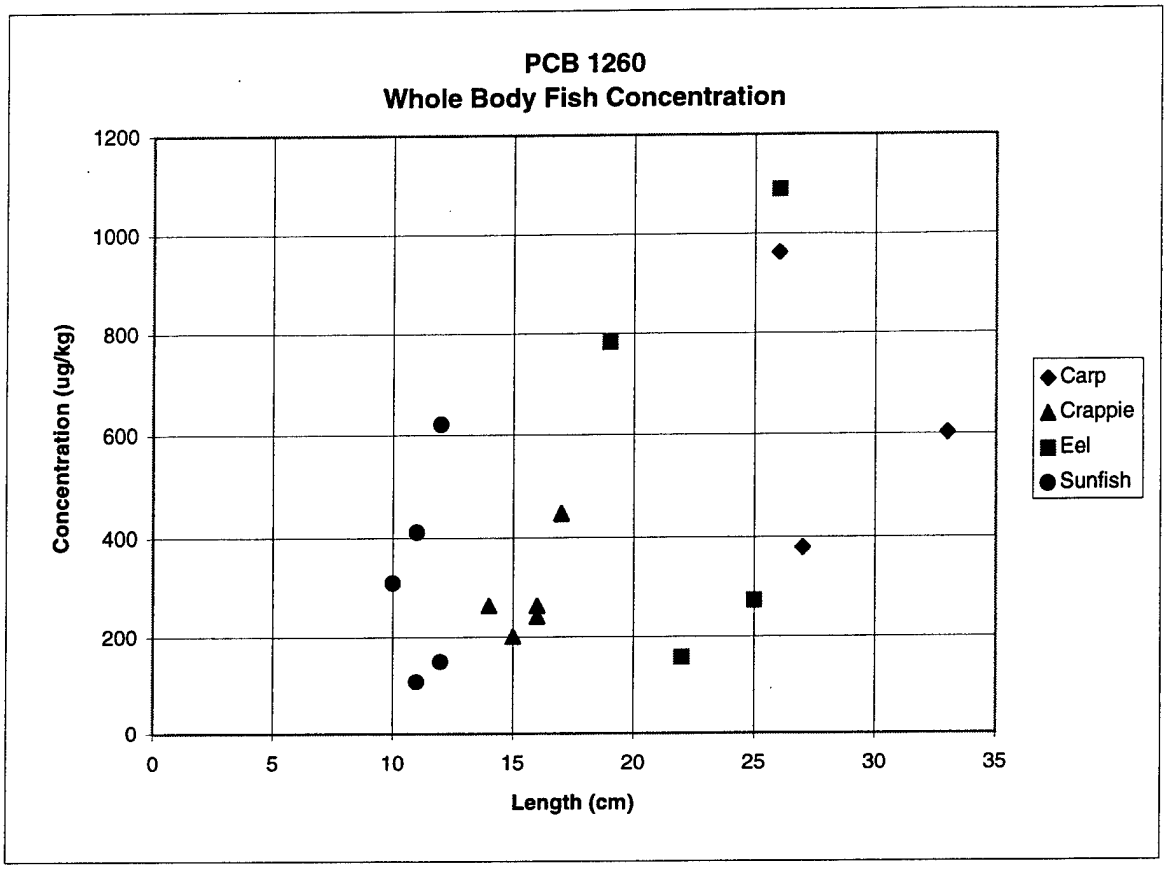

DDD
Lipid Adjusted Whole Body Fish Concentration
Concentration (ug/kg-lipid)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0
5
10
15
20
25
30
35
Length (cm)
ND
ND
ND
ND
Carp
Eel
ND = Not Detected

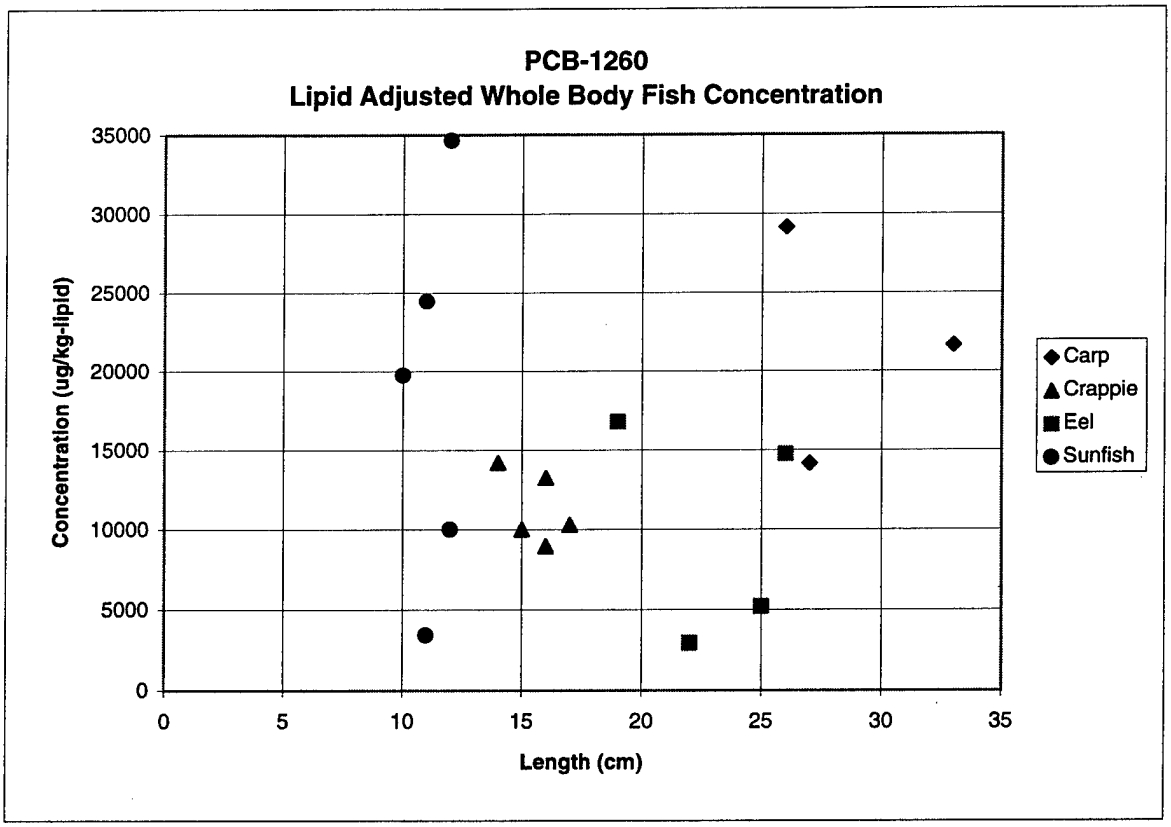

DDE
Whole Body Fish Concentration
Concentration (ug/kg)
180
160
140
120
100
80
60
40
20
0
0
5
10
15
20
25
30
35
Length (cm)
Carp
Crappie
Eel
Sunfish

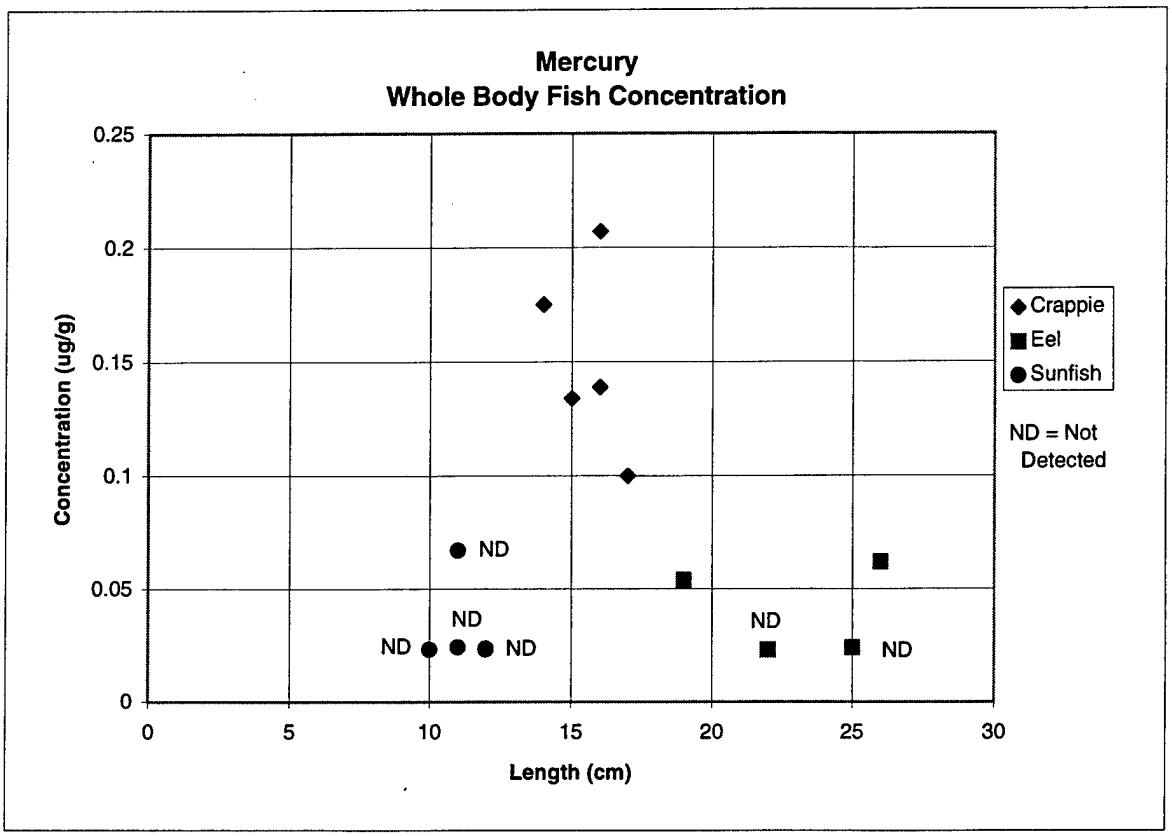

DDE
Lipid Adjusted Whole Body Fish Concentration
Concentration (ug/kg-lipid)
6000
5000
4000
3000
2000
1000
0
0
5
10
15
20
25
30
35
Length (cm)
Carp
Crappie
Eel
Sunfish

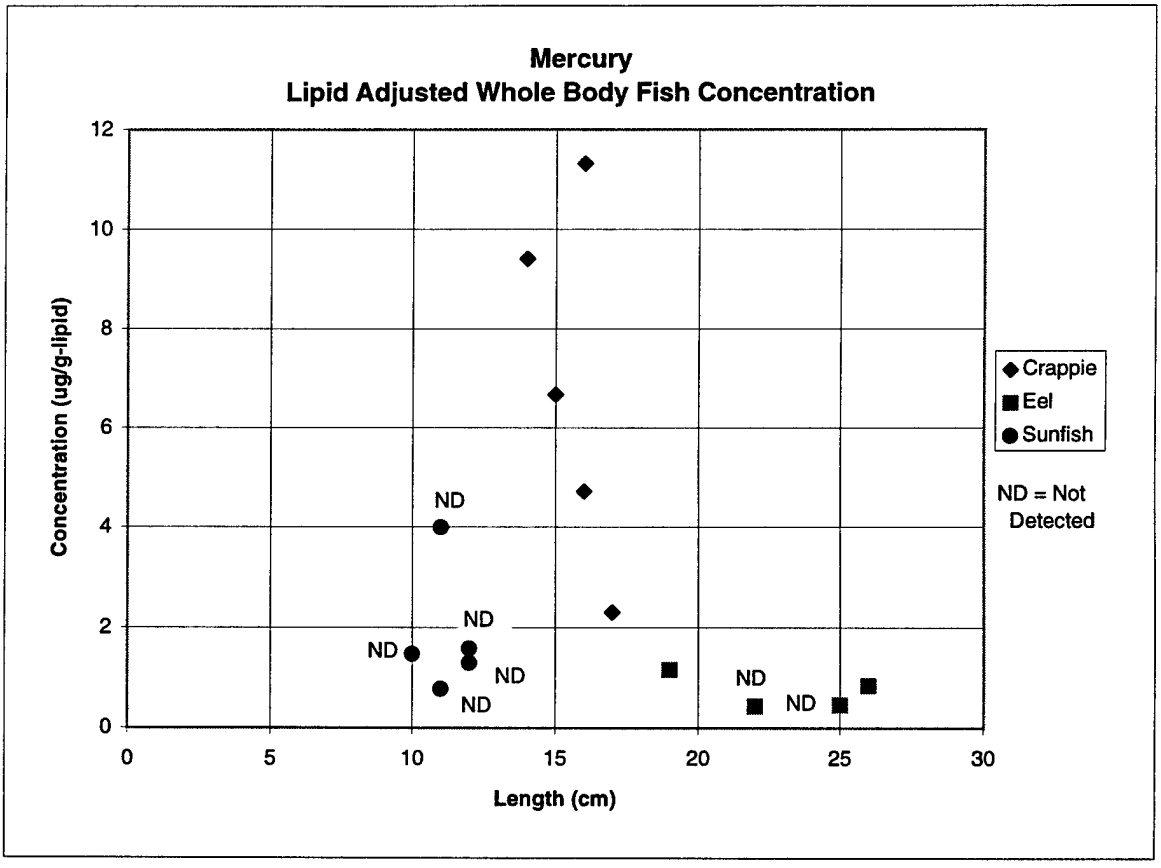

Heptachlor
Whole Body Fish Concentration
Concentration (ug/kg)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
ND
ND
ND
10
10.2
10.4
10.6
10.8
11
11.2
11.4
11.6
11.8
12
Length (cm)
Sunfish
ND = Not Detected


Heptachlor
Lipid Adjusted Whole Body Fish Concentration
Concentration (ug/kg-lipid)
50
45
40
35
30
25
20
15
10
5
0
ND
ND
ND
ND
10
10.2
10.4
10.6
10.8
11
11.2
11.4
11.6
11.8
12
Length (cm)
Sunfish
ND = Not Detected


PCB 1260
Whole Body Fish Concentration
Concentration (ug/kg)
1200
1000
800
600
400
200
0
0
5
10
15
20
25
30
35
Length (cm)
Carp
Crappie
Eel
Sunfish

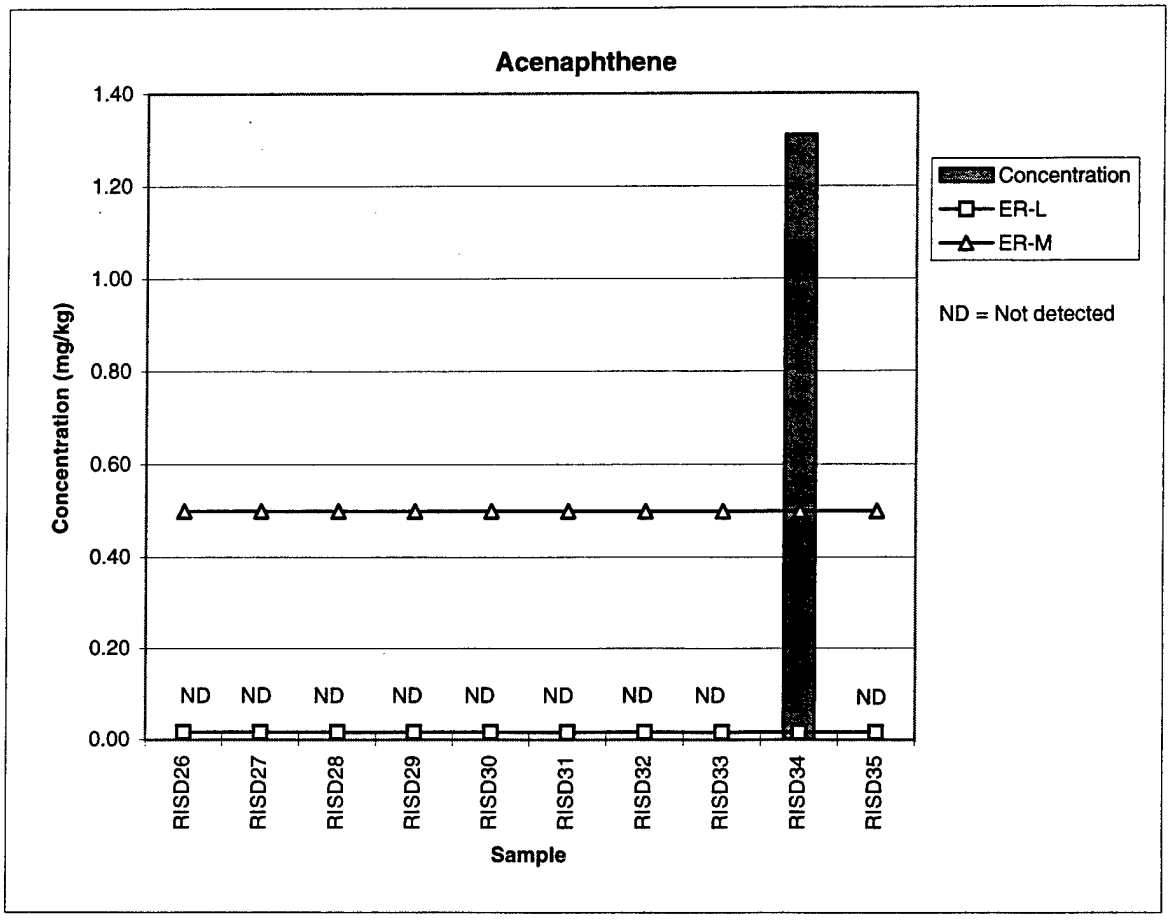

PCB-1260
Lipid Adjusted Whole Body Fish Concentration
Concentration (ug/kg-lipid)
35000
30000
25000
20000
15000
10000
5000
0
0
5
10
15
20
25
30
35
Length (cm)
Carp
Crappie
Eel
Sunfish

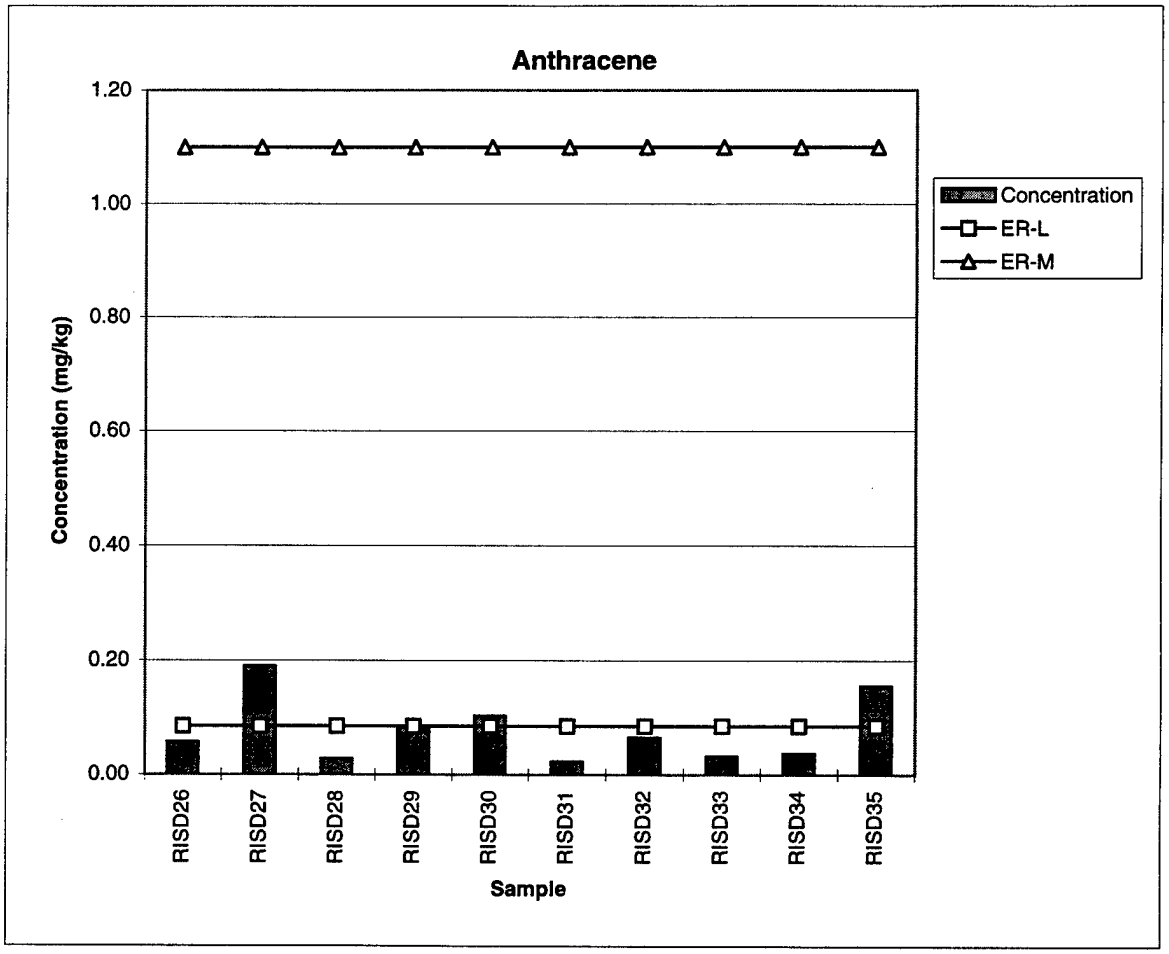

Mercury
Whole Body Fish Concentration
Concentration (ug/g)
0.25
0.2
0.15
0.1
0.05
0
0
5
10
15
20
25
30
Length (cm)
ND
ND
ND
ND
ND
ND
Crappie
Eel
Sunfish
ND = Not Detected


Mercury
Lipid Adjusted Whole Body Fish Concentration
Concentration (ug/g-lipid)
12
10
8
6
4
2
0
0
5
10
15
20
25
30
Length (cm)
ND
ND
ND
ND
ND
ND
ND
Crappie
Eel
Sunfish
ND = Not Detected

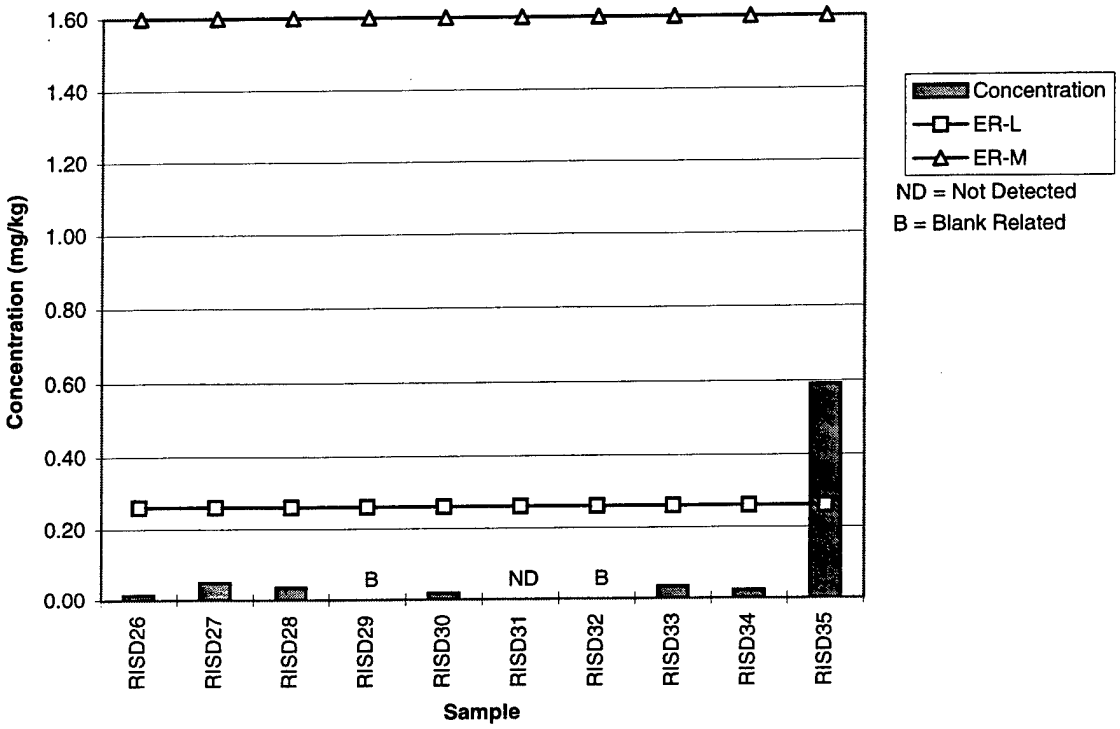
APPENDIX A.3

CHEMICAL CONCENTRATIONS DETECTED AT EACH SEDIMENT SAMPLE LOCATION IN THE OU3 DITCH


Acenaphthene
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Concentration (mg/kg)
ND ND ND ND ND ND ND ND ND
RISD26 RISD27 RISD28 RISD29 RISD30 RISD31 RISD32 RISD33 RISD34 RISD35
Sample
Concentration
ER-L
ER-M
ND = Not detected


Anthracene
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Concentration (mg/kg)
RISD26 RISD27 RISD28 RISD29 RISD30 RISD31 RISD32 RISD33 RISD34 RISD35
Sample
Concentration
ER-L
ER-M

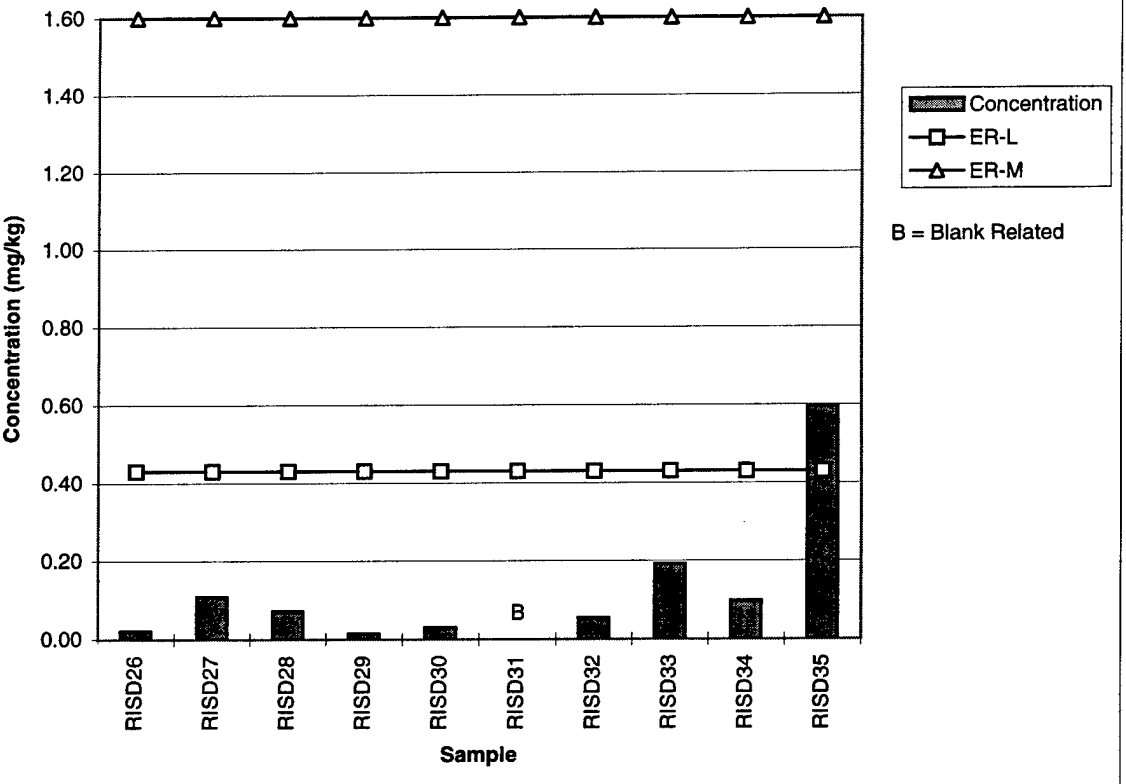
Benzo(a)anthracene



ND = Not Detected

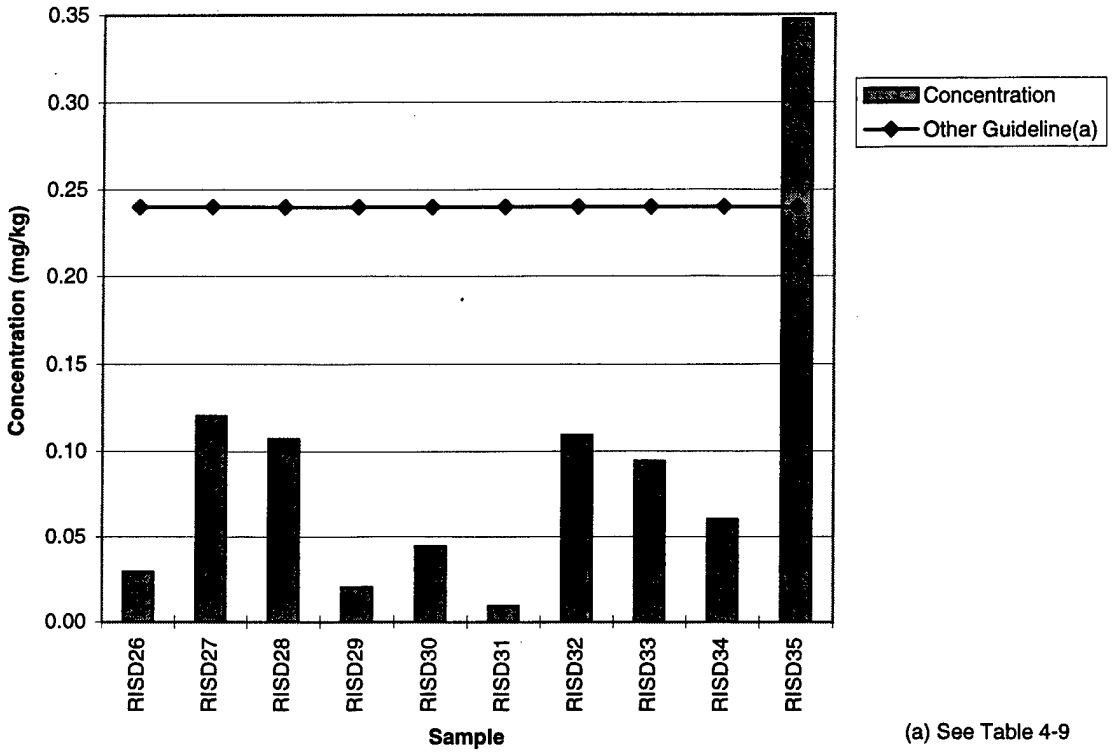
B = Blank Related

Benzo(a)pyrene



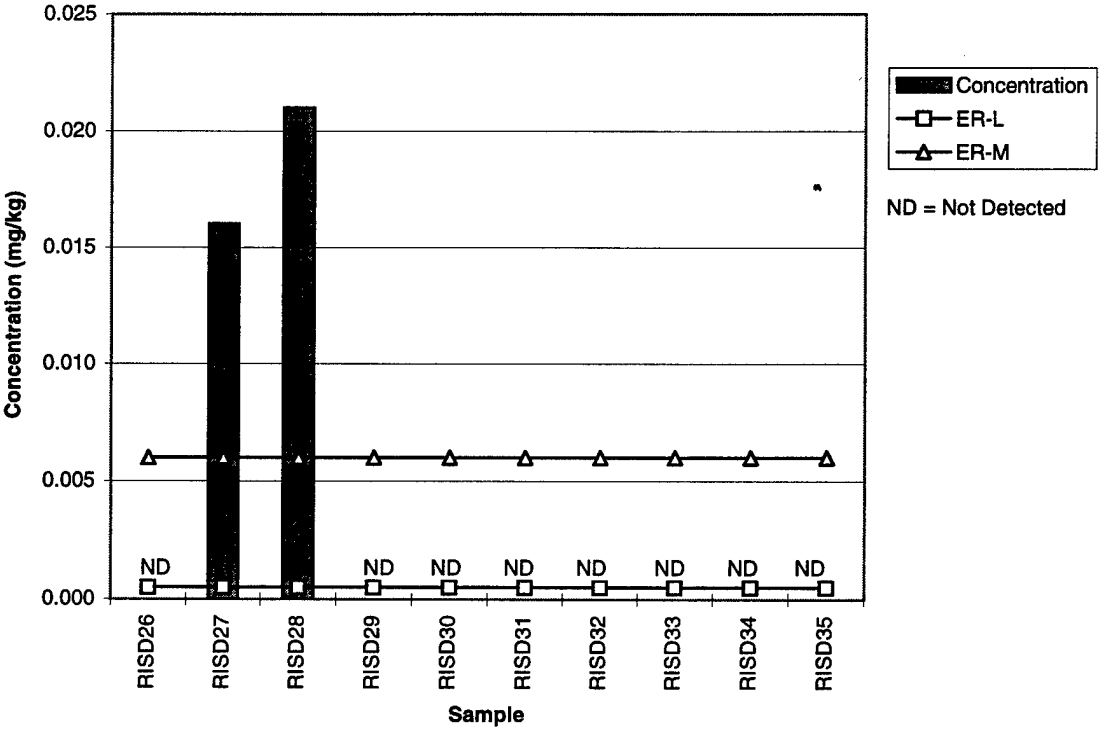
B = Blank Related

Benzo(b)fluoranthene

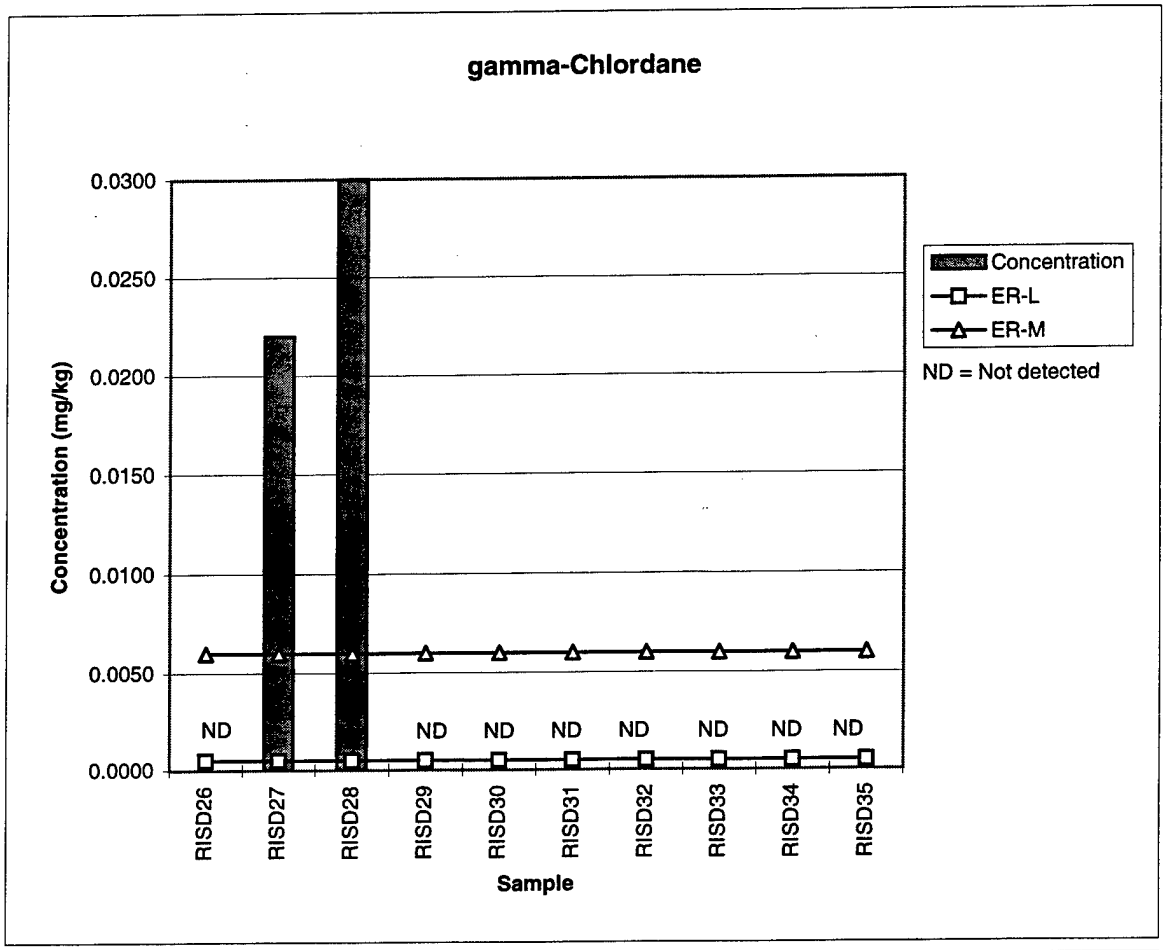


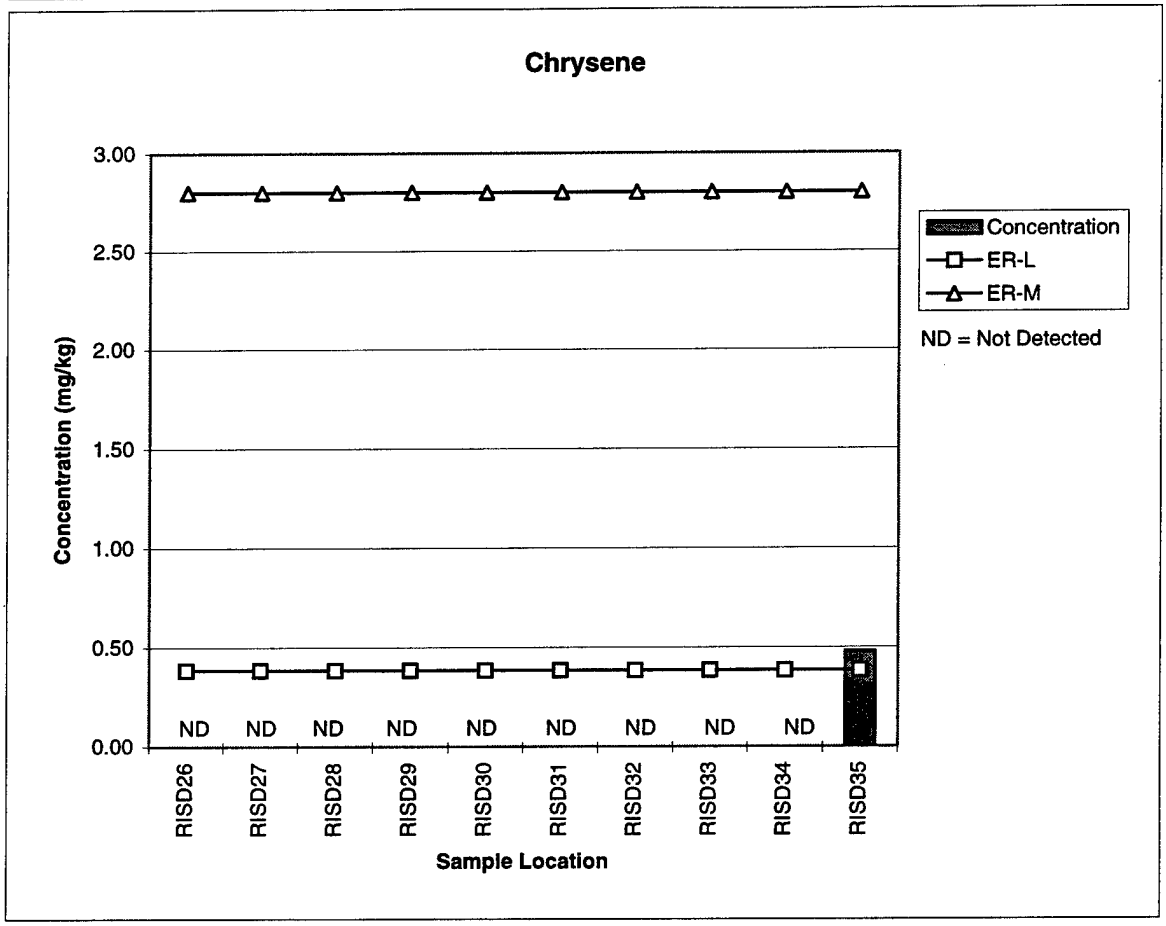
(a) See Table 4-9

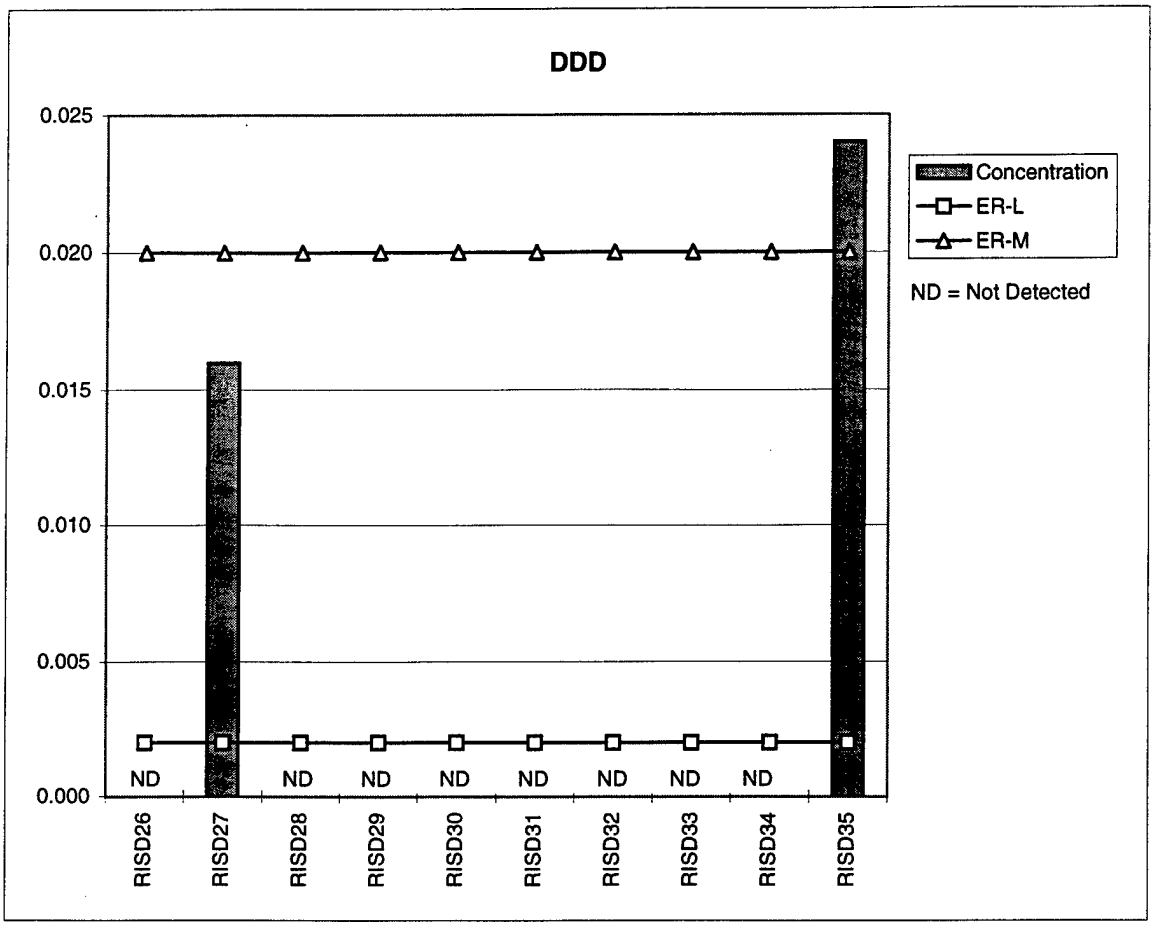
alpha-Chlordane

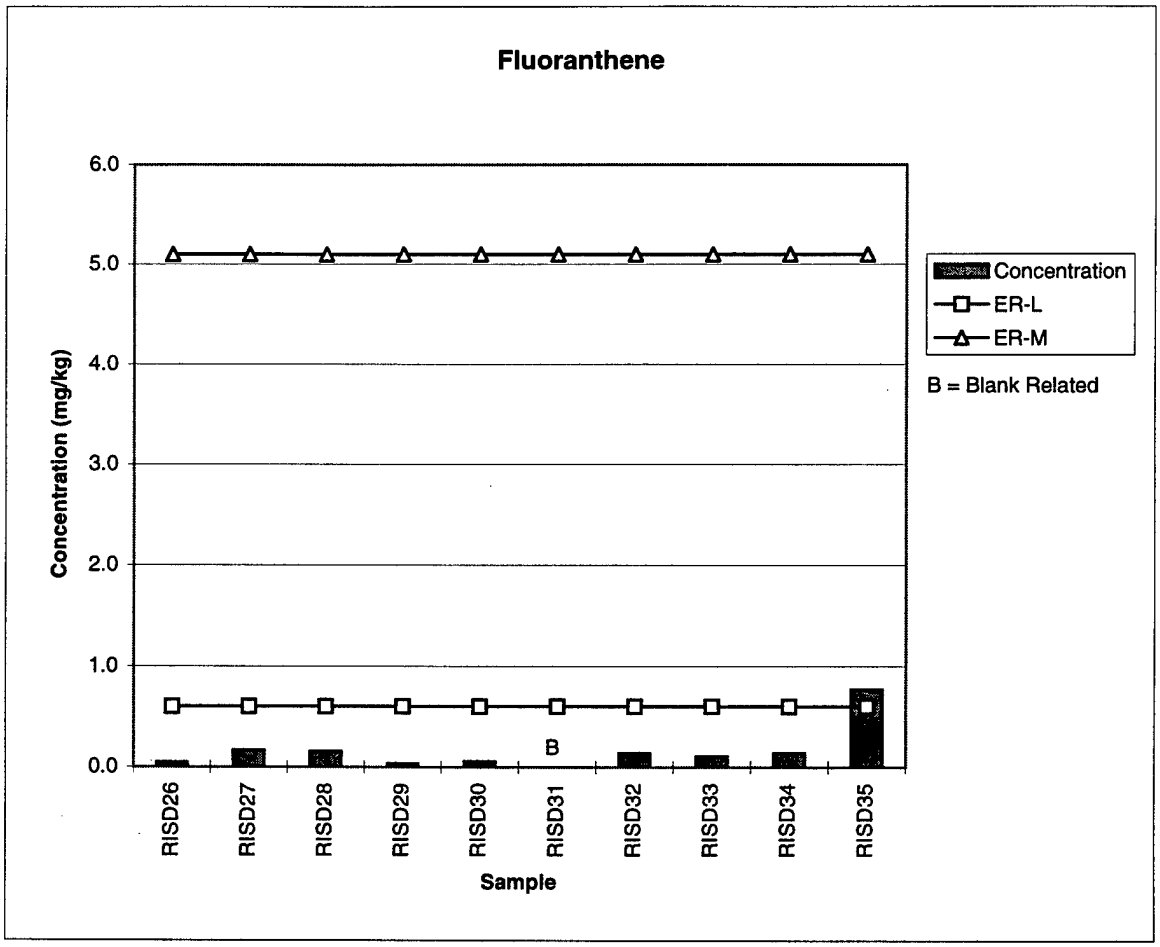


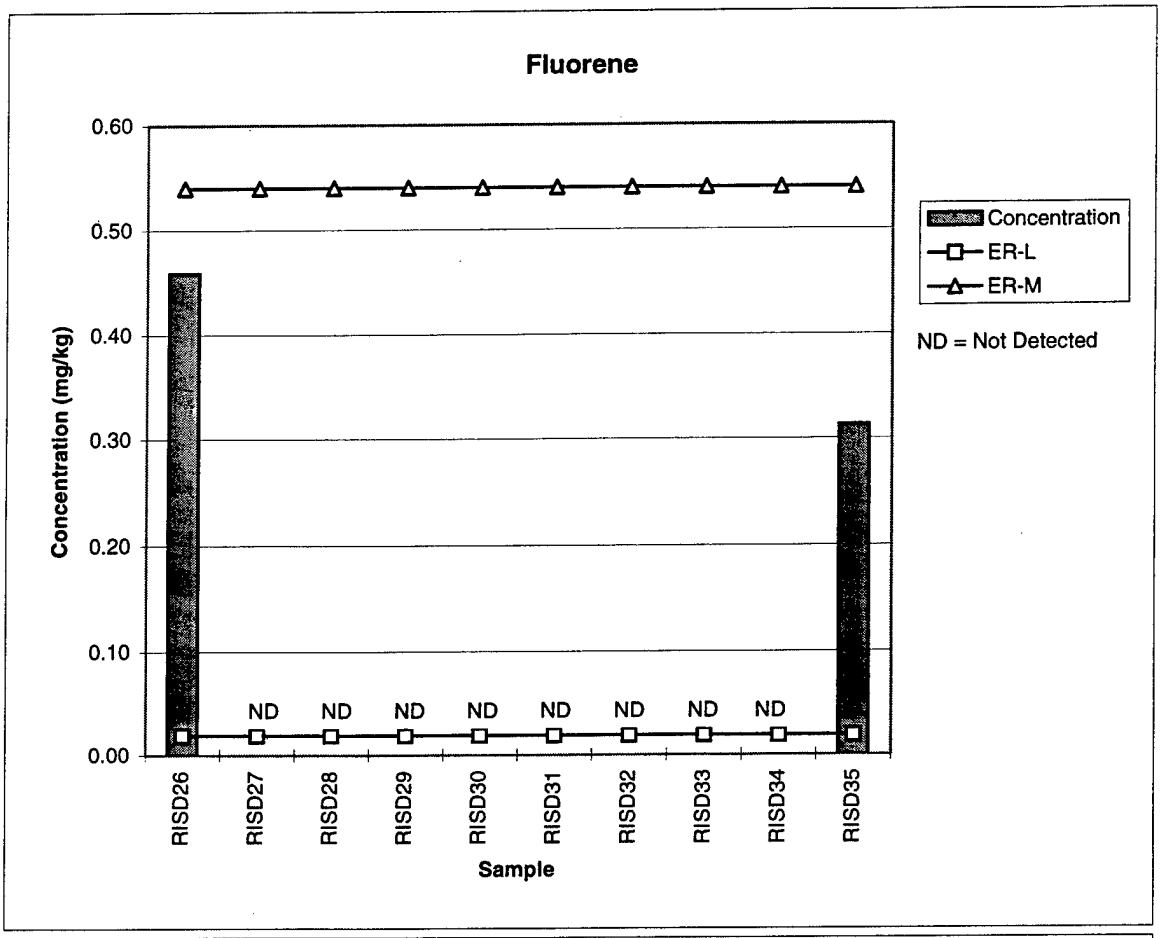
ND = Not Detected

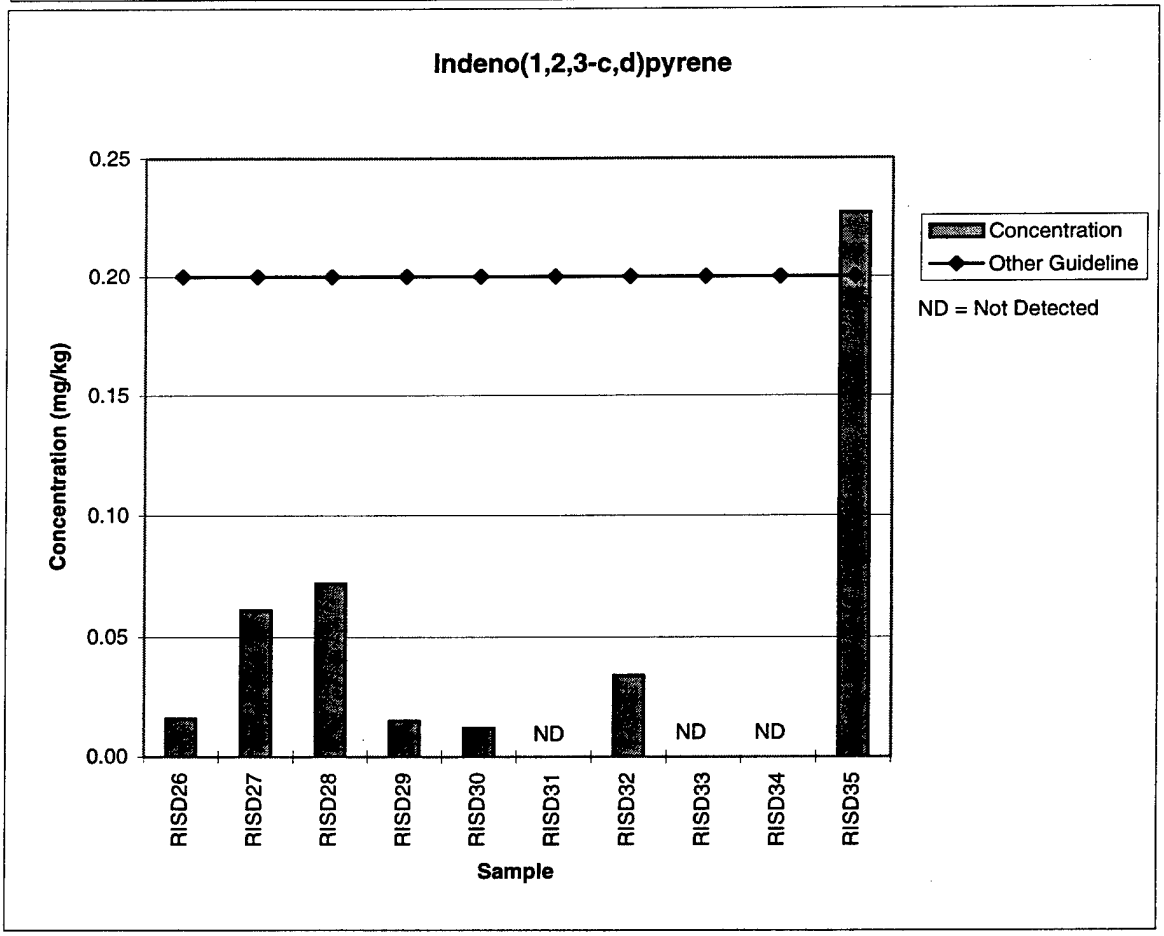

gamma-Chlordane
0.0300
0.0250
0.0200
0.0150
0.0100
0.0050
0.0000
Concentration (mg/kg)
ND
ND
ND
ND
ND
ND
ND
ND
RISD26
RISD27
RISD28
RISD29
RISD30
RISD31
RISD32
RISD33
RISD34
RISD35
Sample
Concentration
ER-L
ER-M
ND = Not detected


Chrysene
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Concentration (mg/kg)
ND
ND
ND
ND
ND
ND
ND
ND
ND
RISD26
RISD27
RISD28
RISD29
RISD30
RISD31
RISD32
RISD33
RISD34
RISD35
Sample Location
Concentration
ER-L
ER-M
ND = Not Detected

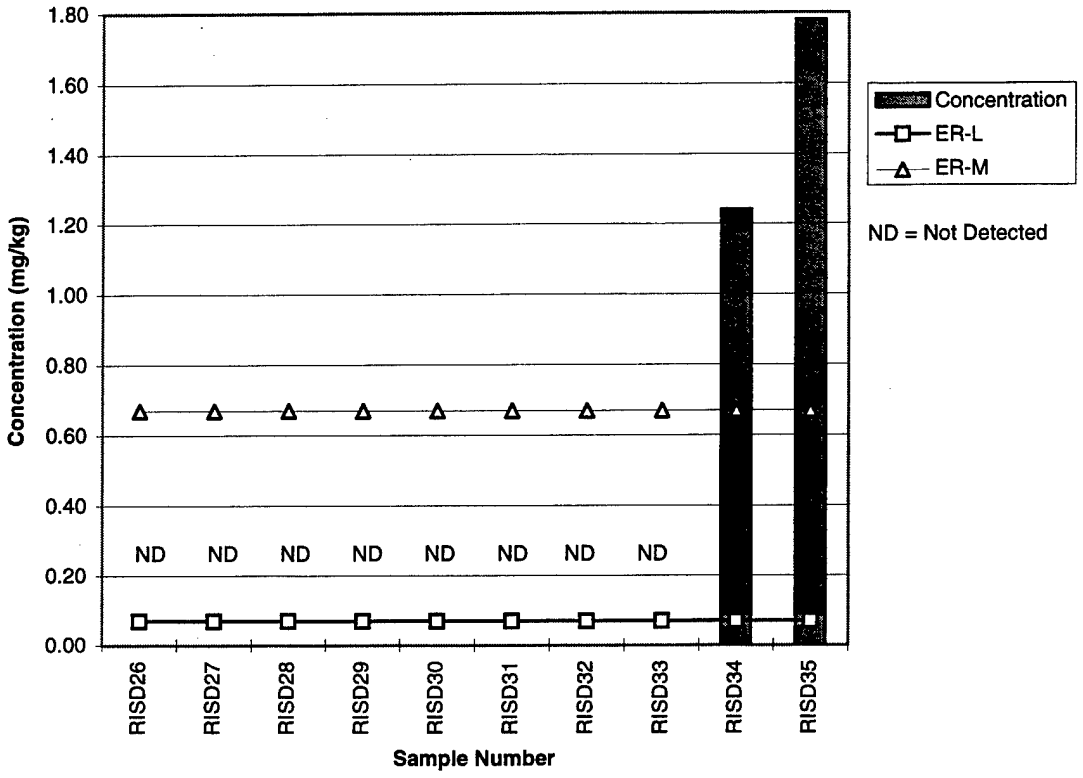

DDD
0.025
0.020
0.015
0.010
0.005
0.000
ND
ND
ND
ND
ND
ND
ND
ND
RISD26
RISD27
RISD28
RISD29
RISD30
RISD31
RISD32
RISD33
RISD34
RISD35
Concentration
ER-L
ER-M
ND = Not Detected


Fluoranthene
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Concentration (mg/kg)
B
RISD26
RISD27
RISD28
RISD29
RISD30
RISD31
RISD32
RISD33
RISD34
RISD35
Sample
Concentration
ER-L
ER-M
B = Blank Related

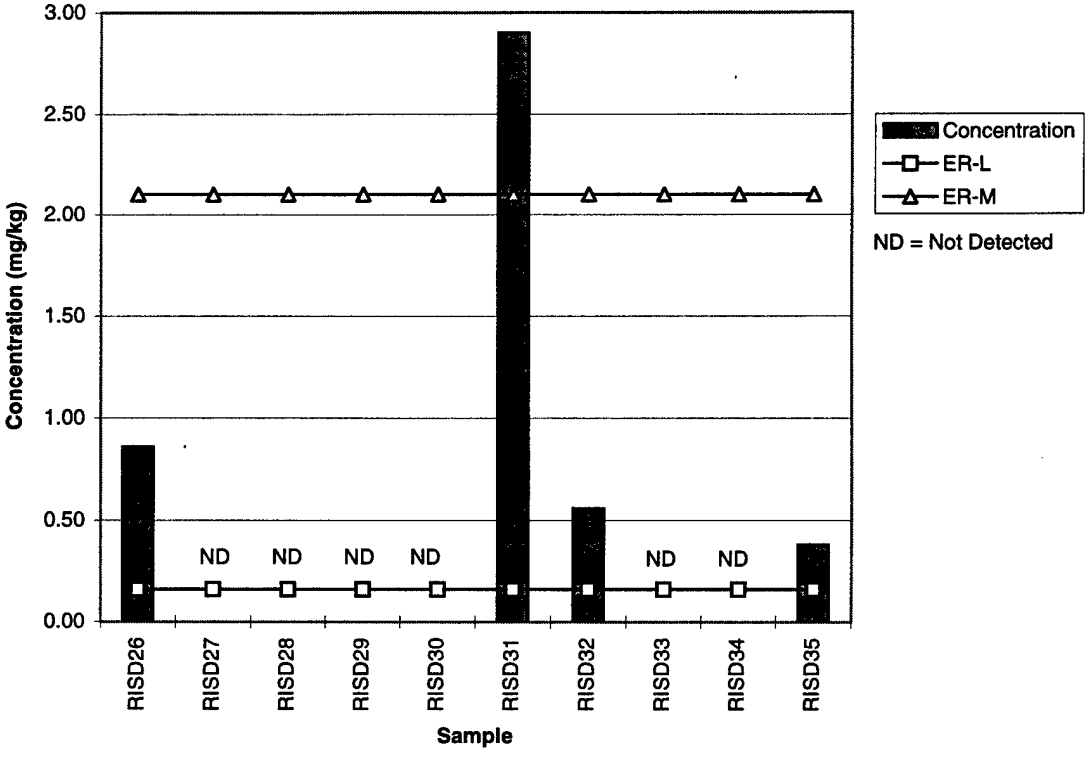

Fluorene
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Concentration (mg/kg)
ND ND ND ND ND ND ND ND
RISD26 RISD27 RISD28 RISD29 RISD30 RISD31 RISD32 RISD33 RISD34 RISD35
Sample
Concentration
ER-L
ER-M
ND = Not Detected


Indeno(1,2,3-c,d)pyrene
0.25
0.20
0.15
0.10
0.05
0.00
Concentration (mg/kg)
ND ND ND
RISD26 RISD27 RISD28 RISD29 RISD30 RISD31 RISD32 RISD33 RISD34 RISD35
Sample
Concentration
Other Guideline
ND = Not Detected

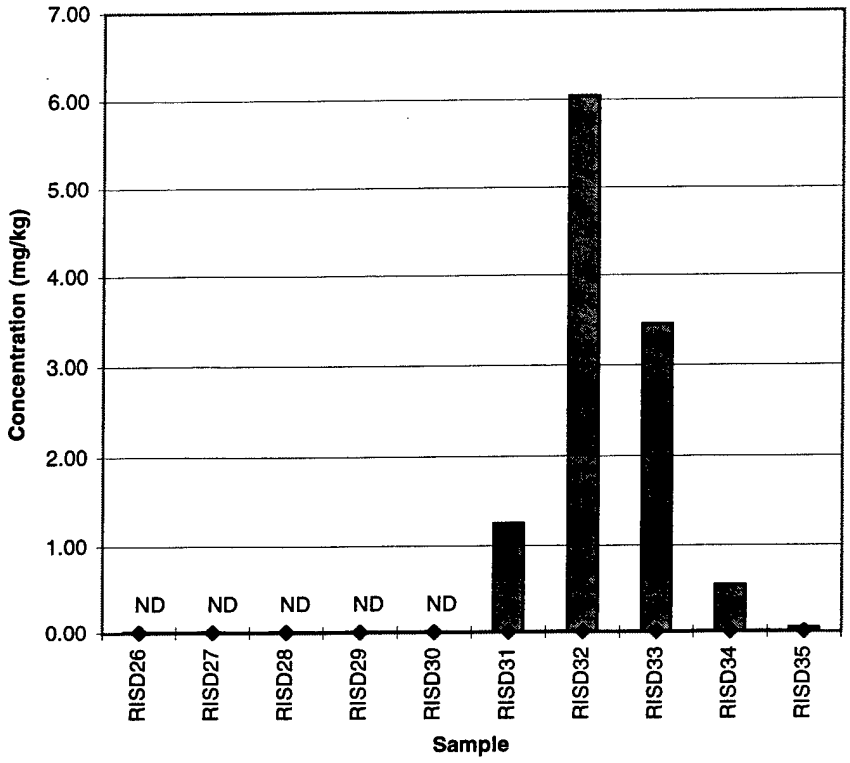
2-Methylnapthalene



Napthalene

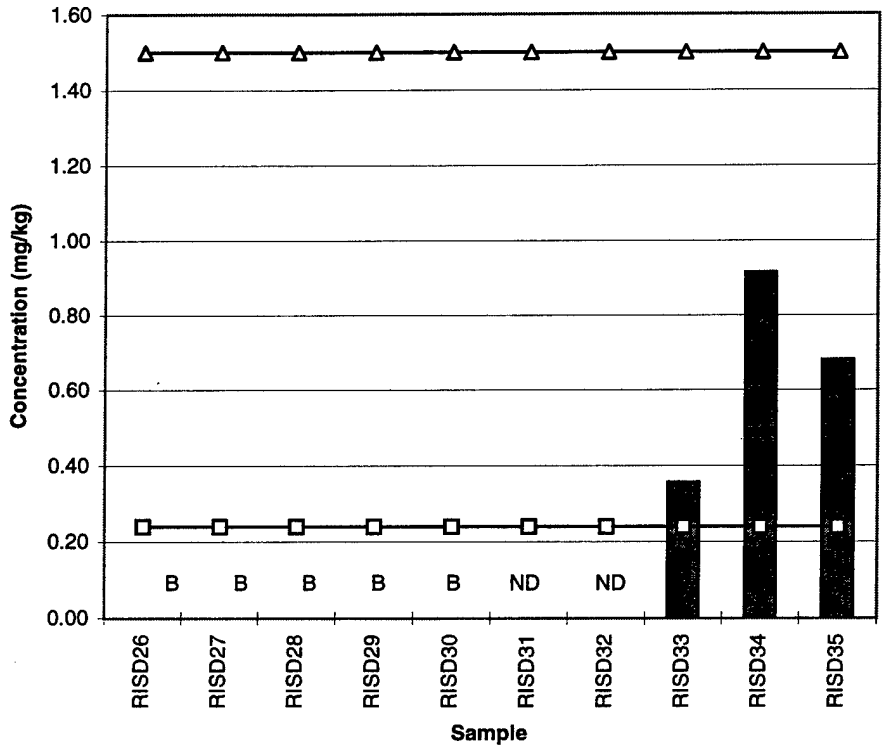


PCB-1260

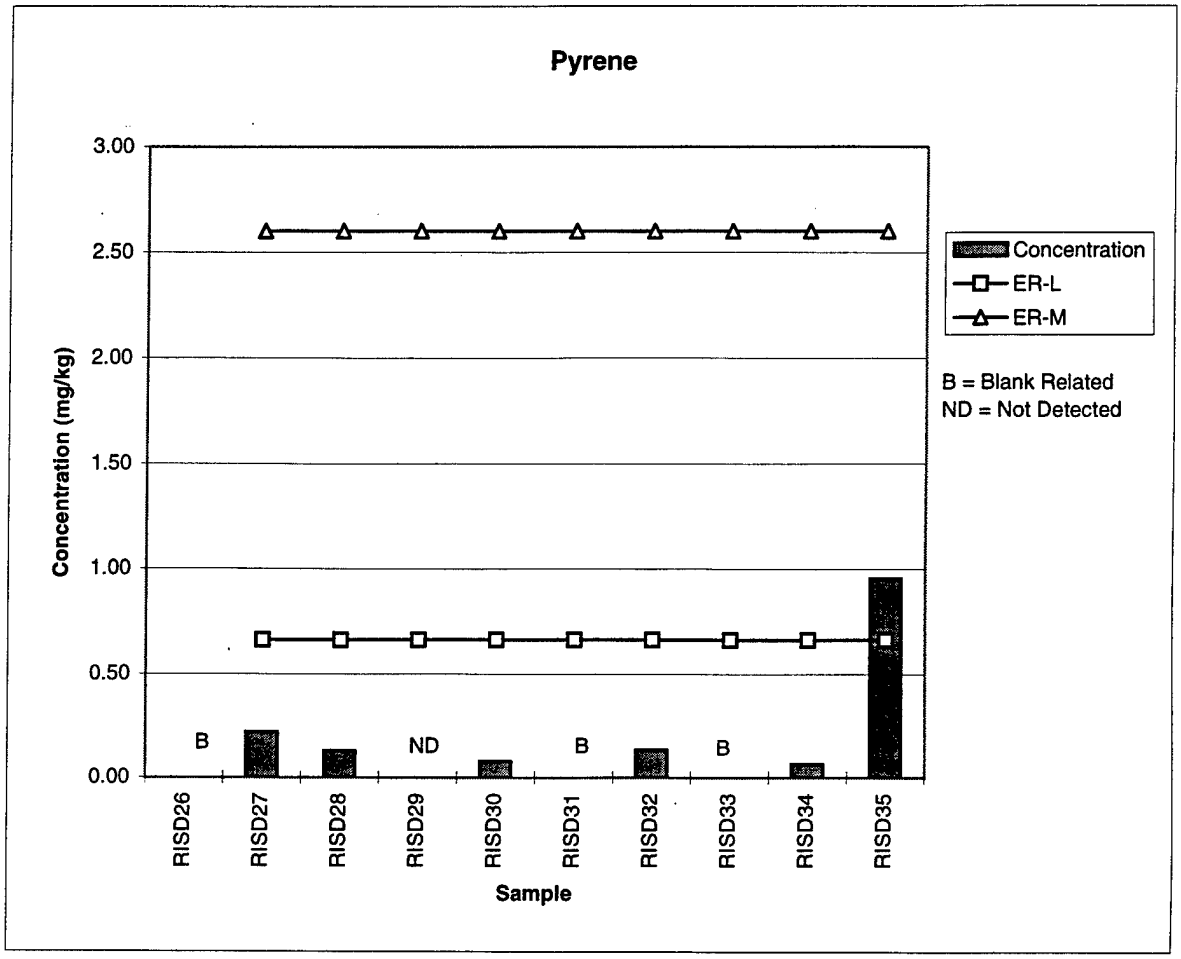


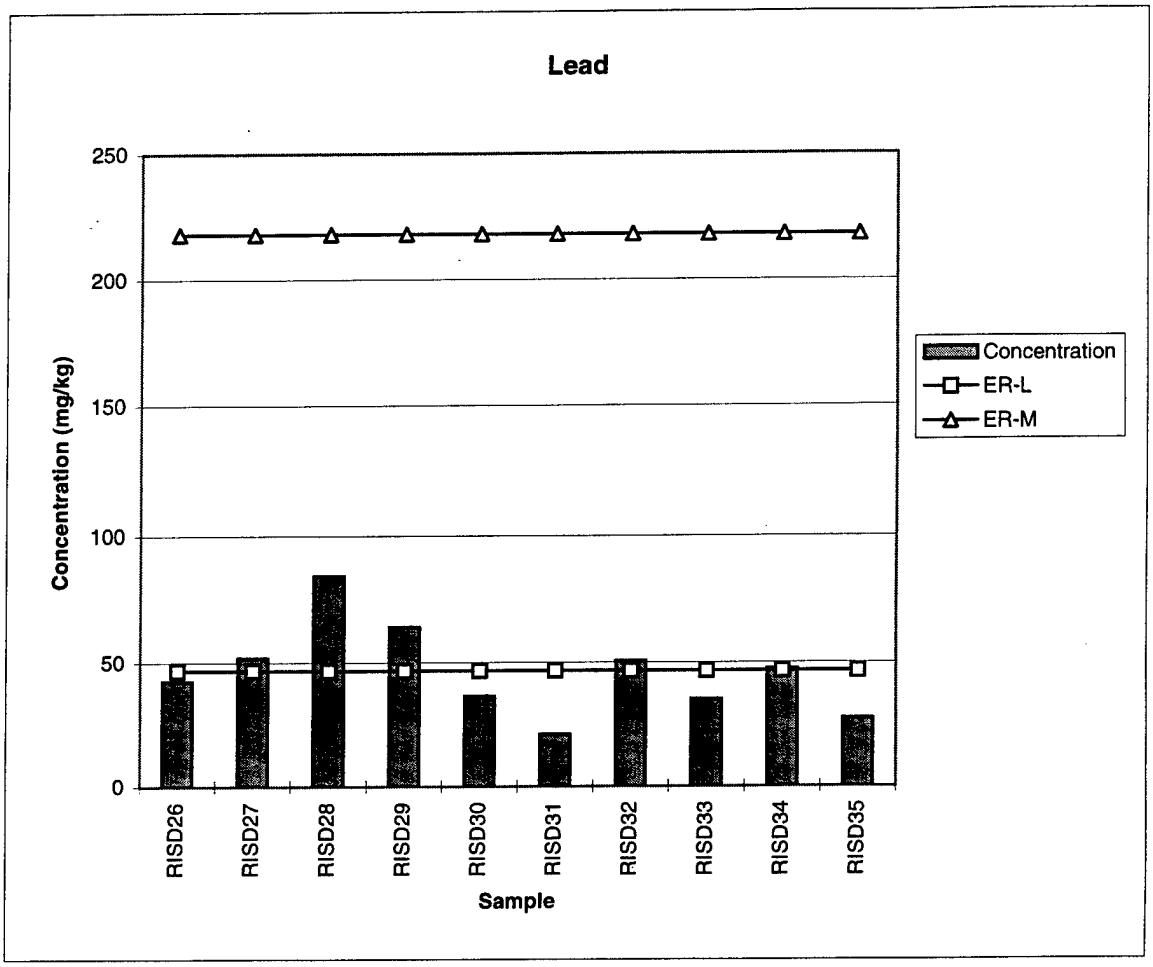
(a) See Table 4-9.

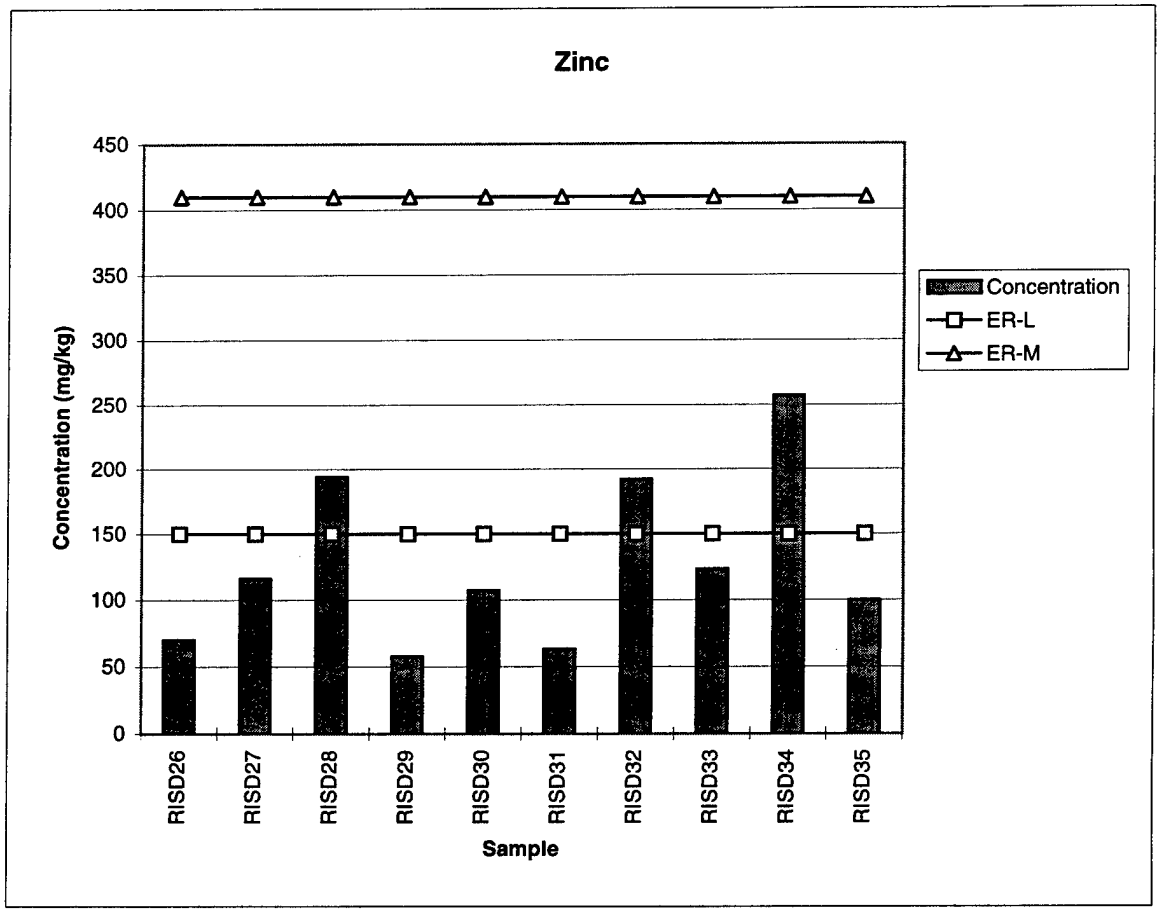
Phenanthrene



B = Blank Related
ND = Not Detected


Pyrene
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Concentration (mg/kg)
B
ND
B
B
RISD26
RISD27
RISD28
RISD29
RISD30
RISD31
RISD32
RISD33
RISD34
RISD35
Sample
Concentration
ER-L
ER-M
B = Blank Related
ND = Not Detected

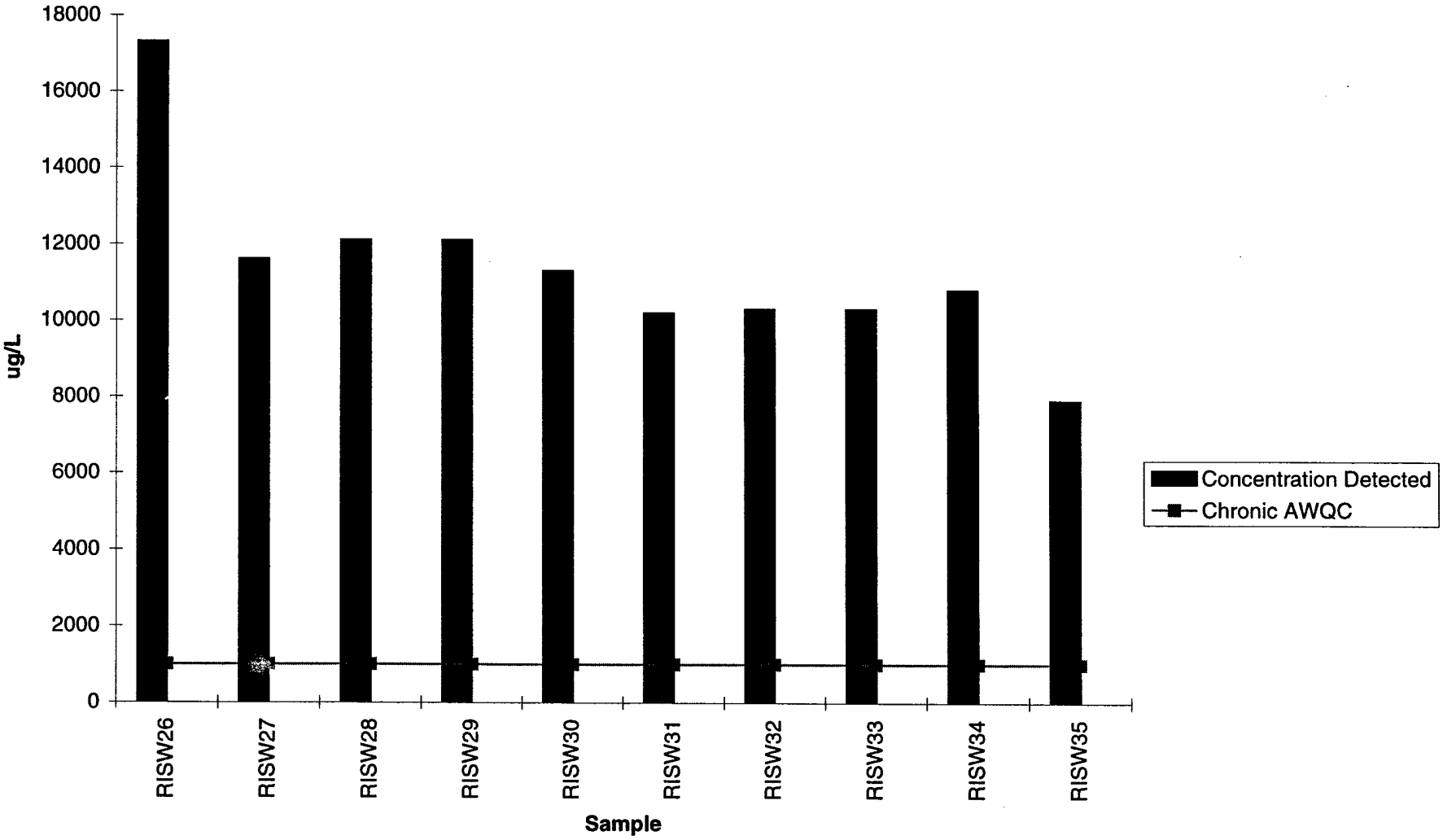

Lead
250
200
150
100
50
0
Concentration (mg/kg)
Concentration
ER-L
ER-M
RISD26
RISD27
RISD28
RISD29
RISD30
RISD31
RISD32
RISD33
RISD34
RISD35
Sample


Zinc
450
400
350
300
250
200
150
100
50
0
Concentration (mg/kg)
Concentration
ER-L
ER-M
RISD26
RISD27
RISD28
RISD29
RISD30
RISD31
RISD32
RISD33
RISD34
RISD35
Sample

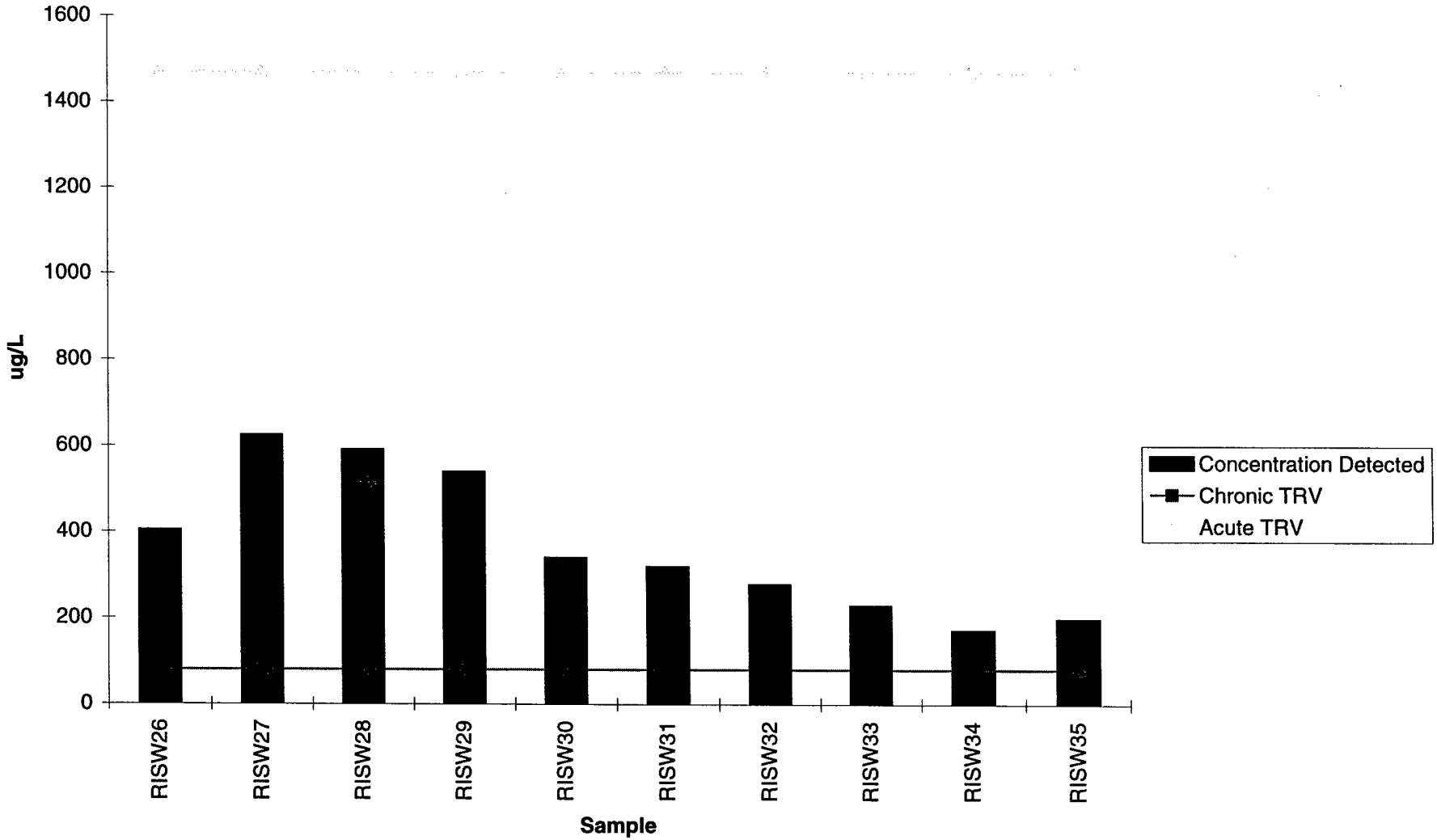
APPENDIX A.4

CHEMICAL CONCENTRATIONS DETECTED AT EACH SURFACE WATER SAMPLE LOCATION IN THE OU3 DITCH

Iron


18000
16000
14000
12000
10000
8000
6000
4000
2000
0
ug/L
RISW26
RISW27
RISW28
RISW29
RISW30
RISW31
RISW32
RISW33
RISW34
RISW35
Sample
Concentration Detected
Chronic AWQC

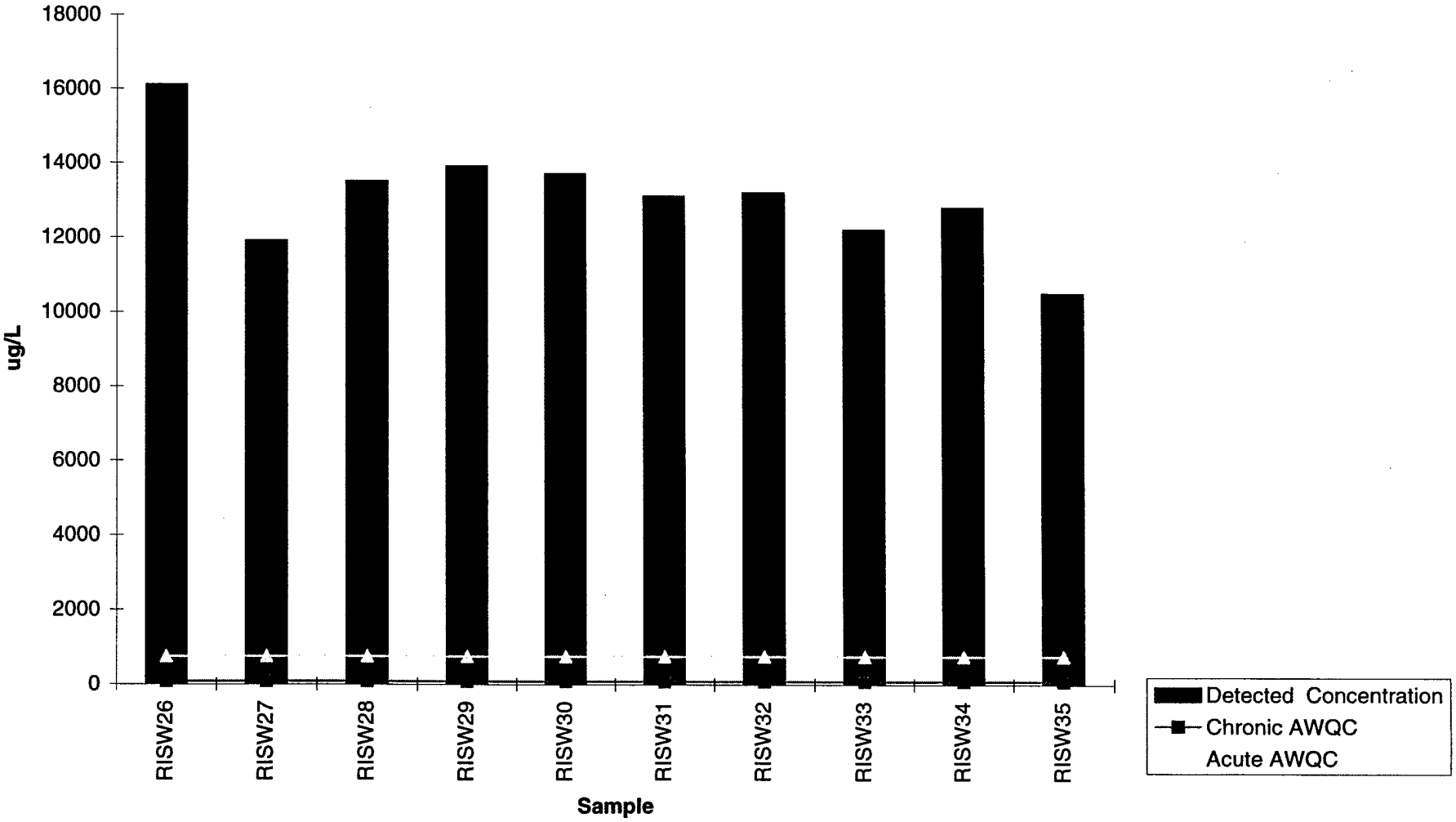
Manganese

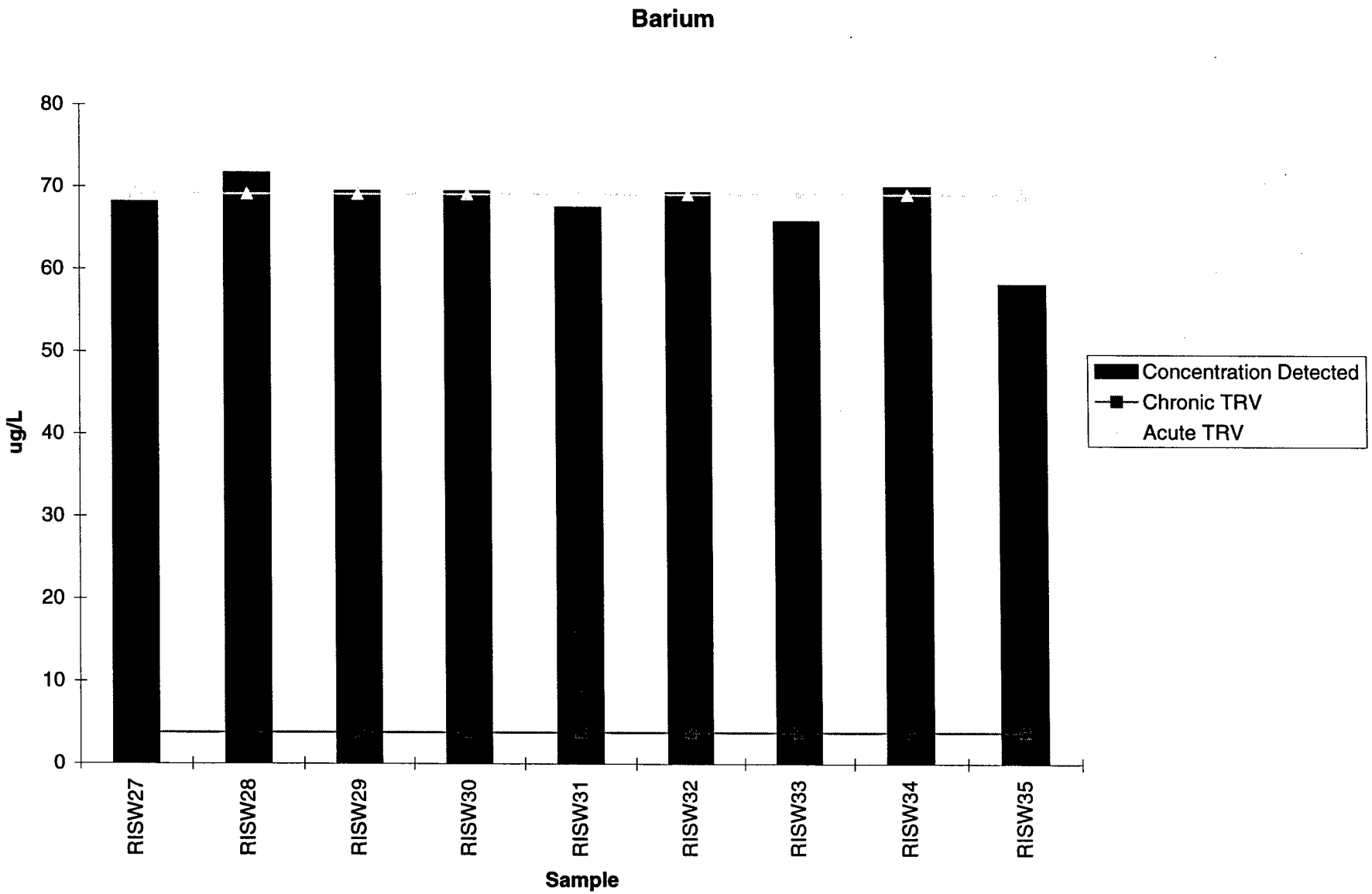

1600
1400
1200
1000
800
600
400
200
0
ug/L
RISW26
RISW27
RISW28
RISW29
RISW30
RISW31
RISW32
RISW33
RISW34
RISW35
Sample
Concentration Detected
Chronic TRV
Acute TRV

APPENDIX A.4

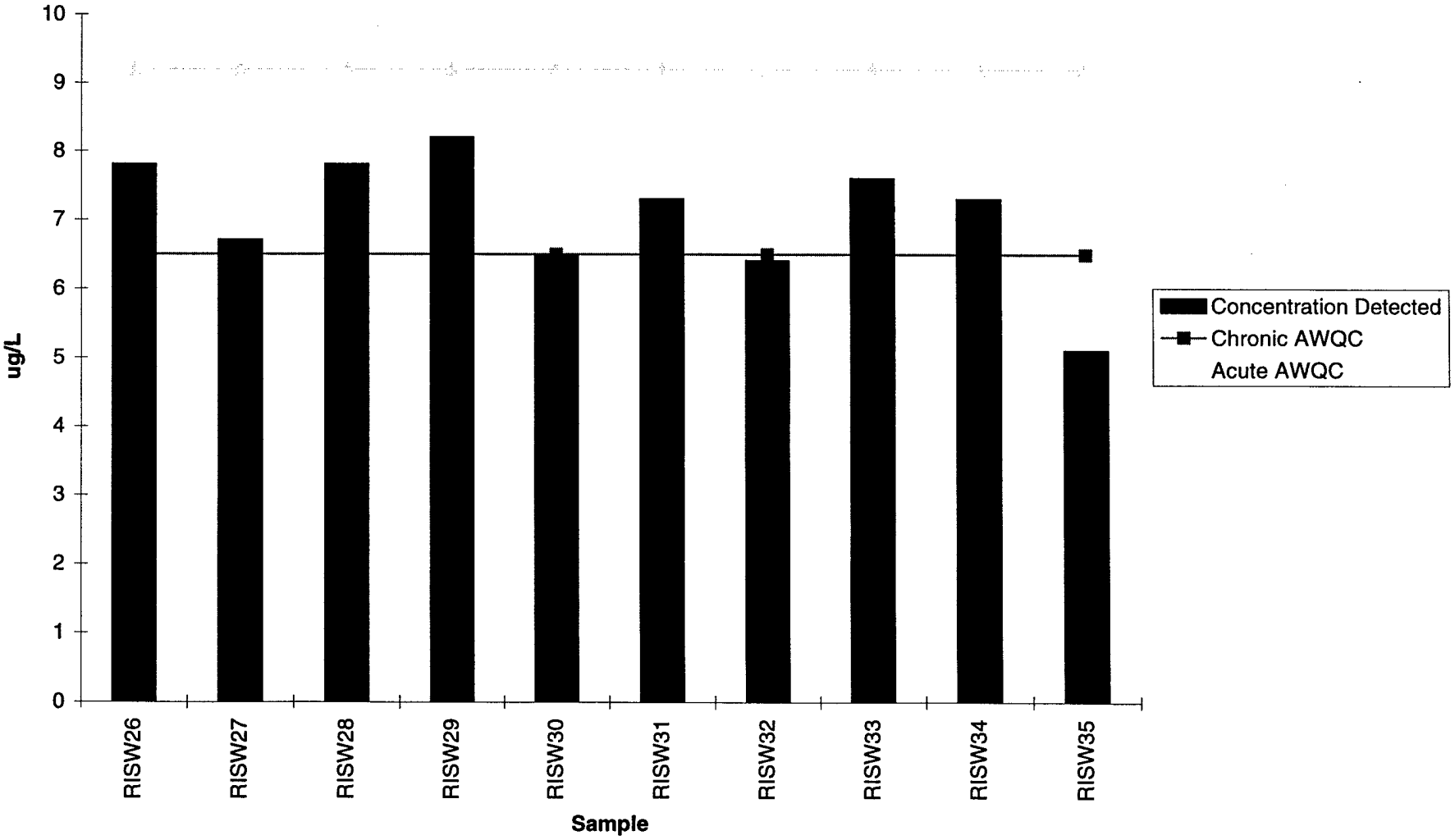
CHEMICAL CONCENTRATIONS DETECTED AT EACH SURFACE WATER SAMPLE LOCATION IN THE OU2 DITCH

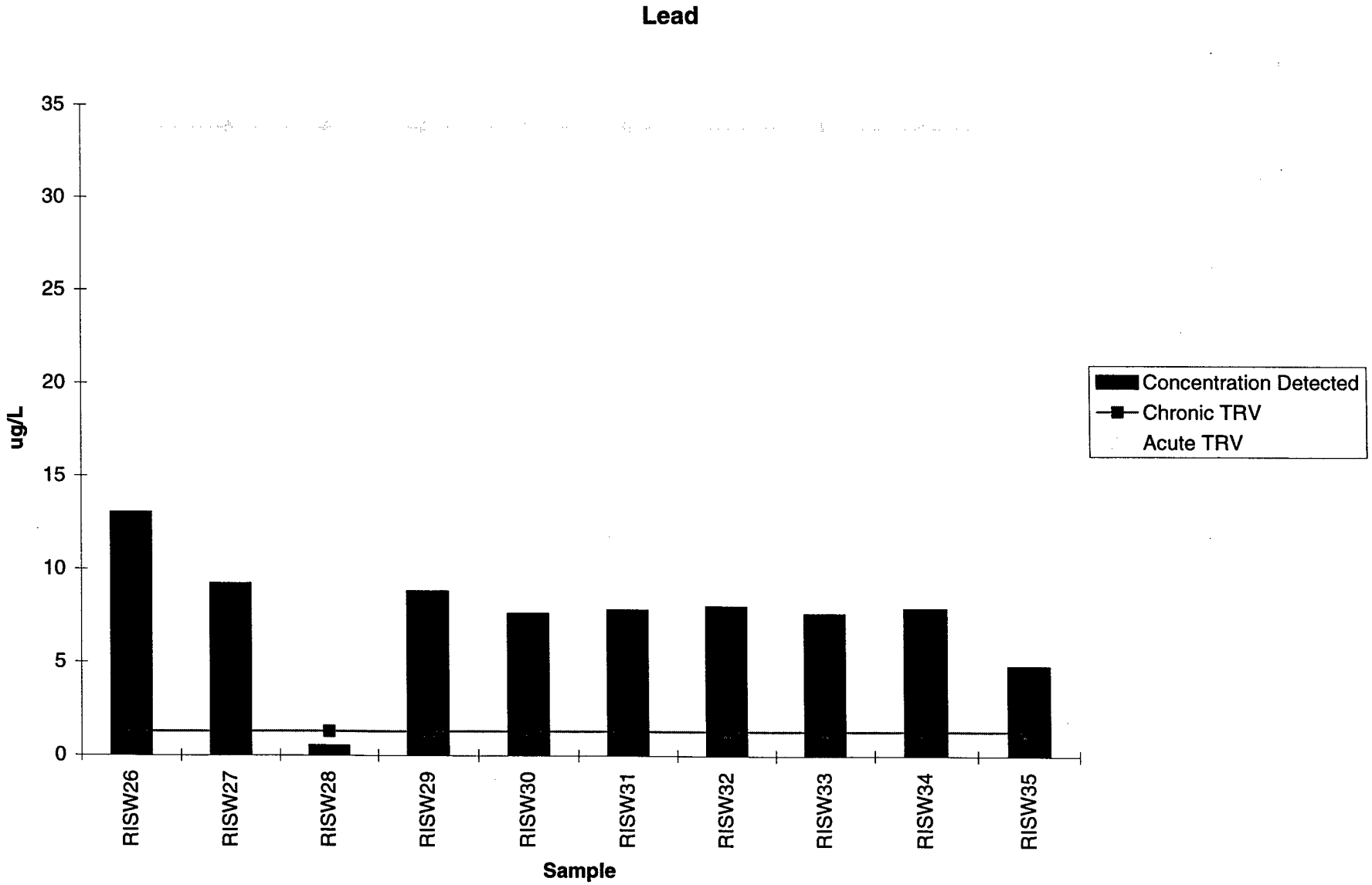
Aluminum


18000
16000
14000
12000
10000
8000
6000
4000
2000
0
ug/L
RISW26
RISW27
RISW28
RISW29
RISW30
RISW31
RISW32
RISW33
RISW34
RISW35
Sample
Detected Concentration
Chronic AWQC
Acute AWQC

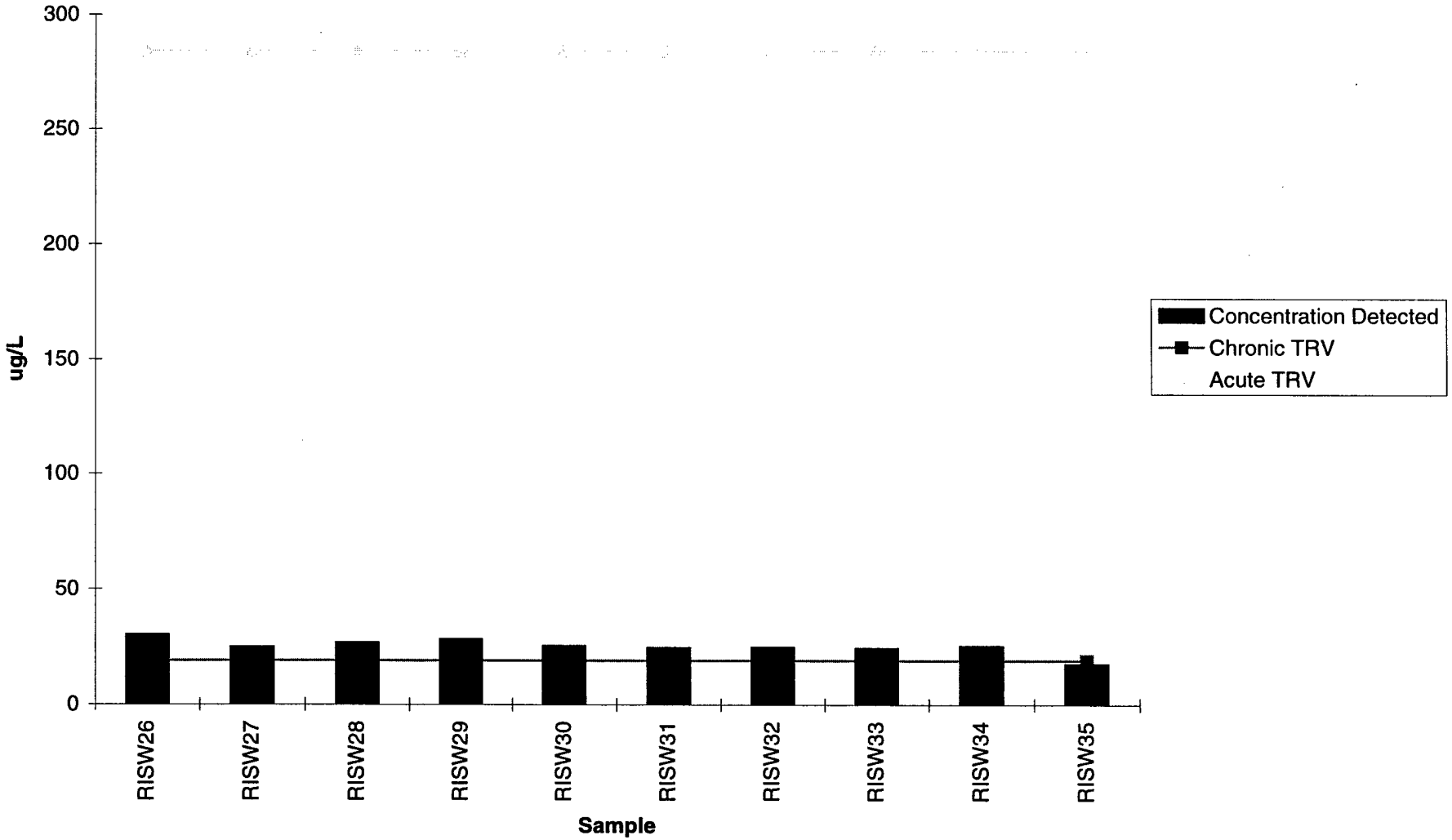

Barium
80
70
60
50
40
30
20
10
0
ug/L
RISW27
RISW28
RISW29
RISW30
RISW31
RISW32
RISW33
RISW34
RISW35
Sample
Concentration Detected
Chronic TRV
Acute TRV

Copper


10
9
8
7
6
5
4
3
2
1
0
ug/L
RISW26
RISW27
RISW28
RISW29
RISW30
RISW31
RISW32
RISW33
RISW34
RISW35
Sample
Concentration Detected
Chronic AWQC
Acute AWQC


Lead
35
30
25
20
15
10
5
0
ug/L
Concentration Detected
Chronic TRV
Acute TRV
RISW26
RISW27
RISW28
RISW29
RISW30
RISW31
RISW32
RISW33
RISW34
RISW35
Sample

Vanadium


300
250
200
150
100
50
0
ug/L
Concentration Detected
Chronic TRV
Acute TRV
RISW26
RISW27
RISW28
RISW29
RISW30
RISW31
RISW32
RISW33
RISW34
RISW35
Sample

APPENDIX B

COST CALCULATION WORKSHEETS

Table B-1. Estimated Annual O&M Cost for Alternative A: No Action

Item	Description	Quantity	Unit of Measure	Unit Cost $	Item Cost $	Reference or Comment
Five Year Report						
1	5-year evaluation required by EPA, 1/5 of report charged each year.	0.2	lump sum	30,000	6,000	
2	Scope contingency	20%			1,200	
	Total annual O&M cost				**7,200**	

Table B-2. Estimated Capital Cost for Alternative B: Natural Attenuation/Long-Term Monitoring with Institutional Controls

Item	Description	Quantity	Unit of Measure	Unit Cost $	Item Cost $	Reference or Comment
Institutional Controls						
1	Limit access to the site	1	lump sum	11,131	11,131	deeds, security, signs
2	Public education program with database	1	lump sum	8,730	8,730	
4	**Subtotal estimated construction cost**				**19,861**	
5	Health and Safety	30%			6,000	
5	Bid contingency	15%			3,000	
6	Scope contingency	15%			3,000	
	Total capital cost				**31,861**	
7	Permitting and legal	5%			2,000	
8	Servicing during construction	0%			0	no construction
9	Design cost	0%			0	no engineering design
	Total estimated capital cost				**33,861**	

Table B-3. Estimated Annual O&M Cost for Alternative B: Natural Attenuation/Long-Term Monitoring with Institutional Controls

Item	Description	Quantity	Unit of Measure	Unit Cost $	Item Cost $	Reference or Comment
Long-term Monitoring						
1	Groundwater sampling	5	sample	1,586	7,930	5 samples each year
2	Surface water sampling	0.4	sample	986	394	2 samples every fifth year
3	Sediment sampling	0.4	sample	1,161	464	2 samples every fifth year
4	Biota sampling	0.4	sample	1,447	579	2 samples every fifth year
	Subtotal of annual sampling and analysis cost				**9,368**	
5	QC samples	10%	subtotal	9,368	937	sampling and analysis subtotal
6	Maintenance on monitoring wells	1	each	500	500	
Five Year Report						
7	Same as Table B-1, line 1				6,000	
	Subtotal estimated annual O&M cost				**16,804**	
8	Scope contingency	6%			1,060	data needs may vary with time
	Total estimated annual O&M cost				**17,865**	

Analytical Cost Table

	Ground-water	Surface Water	Sediment	Biota
Labor	800	200	400	600
PAHs	222	222	261	360
TAL inorganics *	243	243	252	140
water quality param.	100	100	0	0
pest/PCBs	221	221	248	347
Total cost per sample	**1,586**	**986**	**1,161**	**1,447**

* biota inorganics are lead and mercury only.

Table B-4. Estimated Capital Cost for Alternative C: Excavation/Ex-Situ Treatment using Chemical Oxidation/On-Site Placement/Long-Term Monitoring/Institutional Controls

Item	Description	Quantity	Unit of Measure	Unit Cost $	Item Cost $	Reference or Comment
Institutional Controls						
1	Same as Table B-2, line 4				19,861	
Excavation						
2	Site Preparation	1	lump sum	22,000	22,000	
3	Construct access road and dewatering area	1	lump sum	12,200	12,200	
4	Excavation of 550 CY of sediment	1	lump sum	6,800	6,800	
Ex-Situ Treatment using Chemical Oxidation						
5	Treatability study and full-scale operation	1	lump sum	103,700	103,700	
6	Sampling during both phases	1	lump sum	7,800	7,800	
On-Site Placement						
7	Sediment returned to original location	1	lump sum	5,800	5,800	
8	Revegetation	1	lump sum	11,000	11,000	
	Subtotal estimated construction cost				**189,161**	
9	Health and Safety	15%			28,374	
10	Bid contingency	15%			28,374	
11	Scope contingency	14%			25,629	
	Total capital cost				**271,539**	
12	Permitting and legal	10%			27,154	
13	Servicing during construction	10%			27,154	
14	Design cost	10%			27,154	
	Total estimated capital cost				**353,000**	

Table B-5. Estimated Annual O&M Cost for Alternative C: Excavation/Ex-Situ Treatment using Chemical Oxidation/On-Site Placement/Long-Term Monitoring/Institutional Controls

Item	Description	Quantity	Unit of Measure	Unit Cost $	Item Cost $	Reference or Comment
Long-term Monitoring						
1	Groundwater sampling	3	sample	1,586	4,758	3 samples each year
2	Surface water sampling	0.4	sample	986	394	2 samples every fifth year
3	Sediment sampling	0.4	sample	1,161	464	2 samples every fifth year
4	Biota sampling	0.4	sample	1,447	579	2 samples every fifth year
	Subtotal of annual sampling and analysis cost				**6,196**	
5	QC samples	10%	subtotal	6,196	620	sampling and analysis subtotal
6	Maintenance on monitoring wells	1	each	400	400	
Five Year Report						
7	Same as Table B-1, line 1				6,000	
	Subtotal estimated annual O&M cost				**13,215**	
8	Scope contingency	0%			0	
	Total estimated annual O&M cost				**13,215**	

Table B-6. Estimated Capital Cost for Alternative D: Excavation/Bioslurry Treatment/On-Site Placement/Long-Term Monitoring/Institutional Controls

Item	Description	Quantity	Unit of Measure	Unit Cost $	Item Cost $	Reference or Comment
Institutional Controls						
1	Same as Table B-2, line 4				19,861	
Excavation						
2	Site Preparation	1	lump sum	22,000	22,000	
3	Construct access road and dewatering area	1	lump sum	12,200	12,200	
4	Excavation of 550 CY of sediment	1	lump sum	6,800	6,800	
Bioslurry Treatment						
3	Treatability study	1	lump sum	425,000	425,000	
4	Full scale operation	1	lump sum	302,000	302,000	
5	Sampling during both phases	1	lump sum	7,849	7,849	
On-Site Placement						
7	Sediment returned to original location	1	lump sum	5,800	5,800	
8	Revegetation	1	lump sum	11,000	11,000	
	Subtotal estimated construction cost				**812,510**	
6	Health and Safety	30%			243,753	
6	Bid contingency	10%			81,251	
7	Scope contingency	15%			122,430	
	Total capital cost				**1,259,944**	
8	Permitting and legal	10%			125,994	
9	Servicing during construction	10%			125,994	
10	Design cost	14%			181,194	
	Total estimated capital cost				**1,693,126**	

Table B-7. Estimated Annual O&M Cost for Alternative D: Excavation/Bioslurry Treatment/On-Site Placement/Long-Term Monitoring/Institutional Controls

Item	Description	Quantity	Unit of Measure	Unit Cost $	Item Cost $	Reference or Comment
Long-term Monitoring						
1	Groundwater sampling	3	sample	1,586	4,758	3 samples each year
2	Surface water sampling	0.4	sample	986	394	2 samples every fifth year
3	Sediment sampling	0.4	sample	1,161	464	2 samples every fifth year
4	Biota sampling	0.4	sample	1,447	579	2 samples every fifth year
	Subtotal of annual sampling and analysis cost				**6,196**	
5	QC samples	10%	subtotal	6,196	620	sampling and analysis subtotal
6	Maintenance on monitoring wells	1	each	400	400	
Five Year Report						
7	Same as Table B-1, line 1				6,000	
	Subtotal estimated annual O&M cost				**13,215**	
8	Scope contingency	0%			0	
	Total estimated annual O&M cost				**13,215**	

Table B-8. Estimated Capital Cost for Alternative E: Stream Construction and Restoration/Long-Term Monitoring/Institutional Controls

Item	Description	Quantity	Unit of Measure	Unit Cost $	Item Cost $	Reference or Comment
Institutional Controls						
1	Same as Table B-2, line 4				19,861	
Stream Construction						
2	Equipment mobilization	1	lump sum	1,400	1,400	
3	Clear and excavate new stream bed	1	lump sum	24,500	24,500	
4	Spread soil onto existing stream	1	lump sum	25,500	25,500	
Stream Restoration						
5	Sediment and erosion control	1	lump sum	50,000	50,000	
6	Vegetation restoration	1	lump sum	35,000	35,000	
	Subtotal estimated construction cost				**136,400**	
7	Health and Safety	25%			34,100	
8	Bid contingency	5%			6,820	
9	Scope contingency	10%			13,640	
	Total capital cost				**190,960**	
10	Permitting and legal	3%			5,729	
11	Servicing during construction	5%			10,354	
12	Design cost	3%			5,729	
	Total estimated capital cost				**212,771**	

Table B-9. Estimated Annual O&M Cost for Alternative E: Stream Construction and Restoration/Long-Term Monitoring/Institutional Controls

Item	Description	Quantity	Unit of Measure	Unit Cost $	Item Cost $	Reference or Comment
Long-term Monitoring						
1	Groundwater sampling	3	sample	1,586	4,758	5 samples once a year
2	Surface water sampling	0.4	sample	986	394	2 samples every fifth year
3	Sediment sampling	0.4	sample	1,161	464	2 samples every fifth year
4	Biota sampling	0.4	sample	1,447	579	2 samples every fifth year
	Subtotal of annual samplaing and analysis cost				**6,196**	
5	QC samples	10%	subtotal	6,196	620	sampling and analysis subtotal
6	Maintenance on monitoring wells	1	each	400	400	Engineer's estimate
7	Maintenance on stream bed	1	each	3,748	3,748	Engineer's estimate
Five Year Report						
7	Same as Table B-1, line 1				6,000	
	Subtotal estimated annual O&M cost				**16,963**	
8	Scope contingency	0%			0	
	Total estimated annual O&M cost				**16,963**	

Table B-10. Estimated Capital Cost for Alternative F: Excavation with Off-Site Disposal in a Landfill/Long-Term Monitoring/Institutional Controls

Item	Description	Quantity	Unit of Measure	Unit Cost $	Item Cost $	Reference or Comment
Institutional Controls						
1	Same as Table B-2, line 4				19,861	
Excavation						
2	Site Preparation	1	lump sum	22,000	22,000	
3	Construct access road and dewatering area	1	lump sum	12,200	12,200	
4	Excavation of 550 CY of sediment	1	lump sum	6,800	6,800	
5	Vegetation restoration	1	lump sum	11,000	11,000	
Off-Site Disposal						
3	Waste characterization	1	lump sum	11,000	11,000	
4	Stabilization	1	lump sum	12,000	12,000	
5	Landfilling	1	lump sum	10,000	10,000	
	Subtotal estimated construction cost				**104,861**	
6	Health and Safety	25%			26,215	
6	Bid contingency	5%			5,243	
7	Scope contingency	10%			10,486	
	Total capital cost				**156,805**	
8	Permitting and legal	15%			23,521	
9	Servicing during construction	10%			15,681	
10	Design cost	5%			8,582	
	Total estimated capital cost				**204,589**	

Table B-11. Estimated Annual O&M Cost for Alternative F: Excavation with Off-Site Disposal in a Landfill/Long-Term Monitoring/Institutional Controls

Item	Description	Quantity	Unit of Measure	Unit Cost $	Item Cost $	Reference or Comment
Long-term Monitoring						
1	Groundwater sampling	3	sample	1,586	4,758	3 samples each year
2	Surface water sampling	0.4	sample	986	394	1 sample every fifth year
3	Sediment sampling	0.4	sample	1,161	464	1 sample every fifth year
4	Biota sampling	0.4	sample	1,447	579	1 sample every fifth year
	Subtotal of annual sampling and analysis cost				**6,196**	
5	QC samples	10%	subtotal	6,196	620	sampling and analysis subtotal
6	Maintenance on monitoring wells	1	each	400	400	
Five Year Report						
7	Same as Table B-1, line 1				6,000	
	Subtotal estimated annual O&M cost				**13,215**	
8	Scope contingency	0%			0	
	Total estimated annual O&M cost				**13,215**	

Table B-12. Summary of Costs for Alternatives

	Alternative	Capital	Annual O&M		Present Worth *
A	No Action	0	7,200	$	109,795
B	Natural Attenuation/LTM/IC	33,861	17,865	$	308,491
C	Excavation/Ex-Situ Chemical Oxidation/On-Site Placement/LTM/IC	353,000	13,215	$	556,148
D	Excavation/Ex-Situ Bioslurry Treatment/On-Site Placement/LTM/IC	1,693,126	13,215	$	1,896,274
E	Stream Construction and Restoration/LTM/IC	212,771	16,963	$	473,535
F	Excavation with Off-Site Disposal in a Landfill/LTM/IC	204,589	13,215	$	407,736

** present worth calculated at an interest rate of 5% over 30 years*